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MASTER MONITOR DISPLAY APPLICATIONS STUDY FOR THE A-7E.(U)
JAN 77 R H SANDERLIN, P E GREER N62269-76-C-0198
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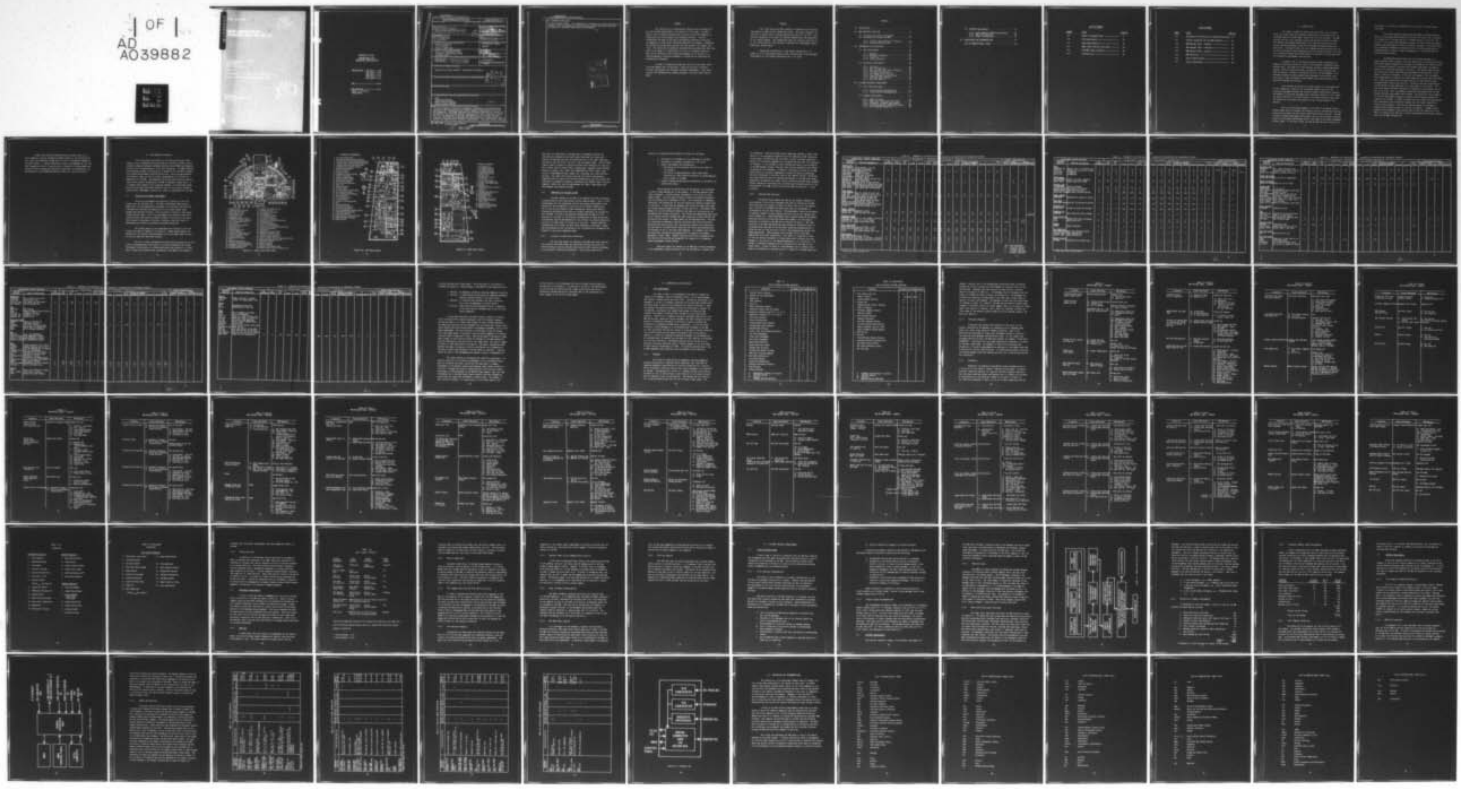

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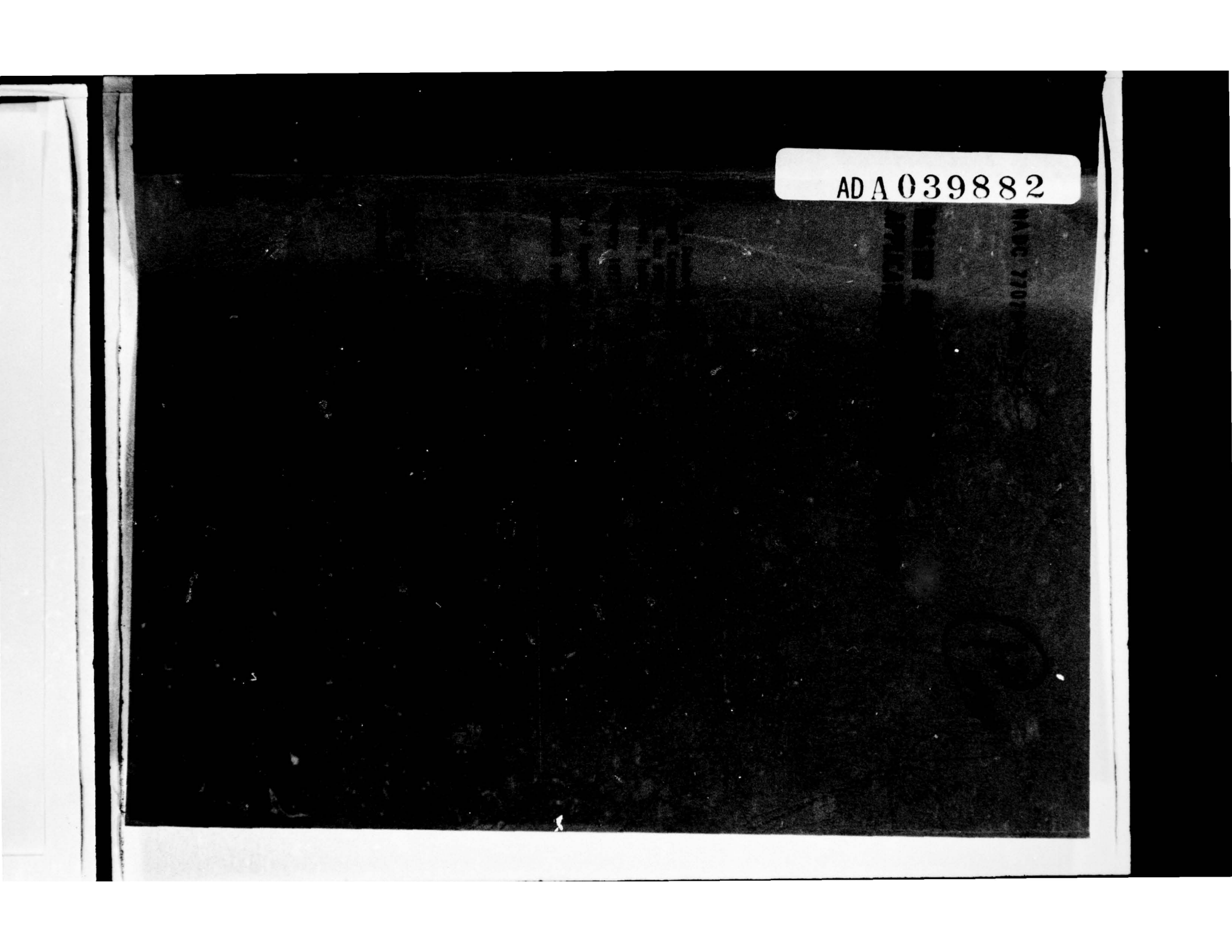

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A study program to define the conceptual requirements and implementation schemes for the incorporation of a Master Monitor Display into an A-7E has been completed. The study identifies the candidate functions for display on the MMD that were selected from the existing A-7E cockpit functions, defines what is to be displayed on the MMD cooresponding to the current warnings, cautions, advisories and auxiliary data with reference to flight modes, and defines the implementation interface requirements. The study results reported

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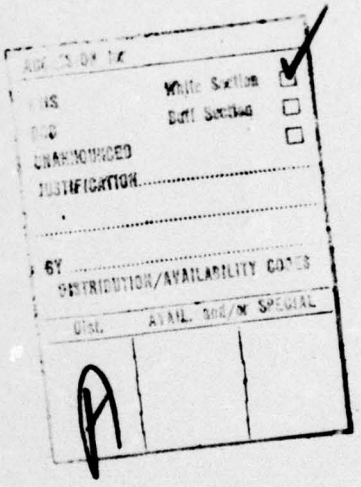
20. ABSTRACT (Continued)

in this document verify the feasibility of utilizing the integrated display concept in an A-7E aircraft to replace certain cockpit functions presently performed with dedicated indicators and instruments.



SUMMARY

The feasibility of incorporating a Master Monitor Display into an A-7E has been established by the results of this study. An alpha-numeric type of display operated under control of the TC-2A computer in conjunction with the necessary pilot-operated controls offers a considerable increase in the useful information presented to the pilot in comparison to the current individual dedicated instruments. Candidates for display on the MMD were selected from the current A-7E cockpit functions. The selection of candidates included those functions that alert the pilot in the event of a malfunction or an out of tolerance condition. When such a condition exists, prestored messages to aid the pilot in decision-making or advisory statements to inform him of situations are automatically displayed.

In order to integrate the MMD into the A-7E three major interface requirements must be satisfied. These are the pilot interface, software requirements, and hardware interface requirements. This report contains the implementation schemes necessary to satisfy these requirements.

PREFACE

This final report has been prepared in compliance with the data requirements of NADC contract N62269-76-C-0198. The report documents the results of a Master Monitor Display Application Study for the A-7E. This work was supported by the Naval Air Systems Command under the sponsorship of Mr. George Tsaparas. The program was under the technical direction of Mr. Bill Mulley and Mr. Karl Quiring of the Naval Air Development Center, Warminster, Pennsylvania.

Significant contributors to this report include Mr. R. H. Sanderlin, E & E Technologies group, under the direction of the principal investigator for the Vought Corporation, Mr. P. E. Greer.

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1.0 INTRODUCTION

The Vought Corporation submits the final report on a 10 month study that established the conceptual feasibility for the application of the Master Monitor Display (MMD) concept into the A-7E aircraft. The MMD provides the pilot with warning, caution and advisory functions through the inflight performance monitoring of all critical aircraft functions (except engine performance) along with preflight and health monitoring activities. The baseline data for this display was derived using the A-7E aircraft functions as being representative of an attack aircraft. Priorities for information display were established as a function of flight mode, and the integration requirements were defined.

The MMD is one of five master displays being conceptually designed for the Navy aircraft as a part of the Advanced Integrated Display System (AIDS). The other four AIDS displays include an Engine Management Display, Vertical Situation Display, Horizontal Situation Display and Head Up Display. The Navy is currently active in the development of the Advanced Integrated Display System which promises to provide the tools with which to stem the present trend towards overcrowding cockpits with dedicated displays and controls.

This improved utilization of cockpit space will be accomplished by the integration of many of the individual display functions into logically programmed displays and controls thereby significantly reducing the numbers of dedicated instruments and indicators required in the cockpit. The major objective of the AIDS concept is to reduce the pilots work load and improve his efficiency particularly in the critical phases of his mission.

One of the principal segments of the AIDS is the Master Monitor Display (MMD) which is assigned the warning, caution, and advisory functions along with preflight and post flight health monitoring activities. The MMD provides inflight performance monitoring of all critical aircraft functions except for the engine performance which is provided on the Engine Management Display (EMD). In the AIDS concept the EMD and MMD can serve as back-up to

one another in the event of a malfunction or failure in either display subsystem.

The studies reported herein were performed to develop baseline data for a conceptual MMD installation for an A-7E cockpit and to evaluate the feasibility of the application of the MMD concept to the A-7E. The results of this study were intended to support the AIDS System Development studies being performed by another contractor thru NADC. The study results were presented incrementally through a series of contractor data interchange meetings to insure a timely dissemination of the needed data for the AIDS system studies.

The MMD applications study for the A-7E was performed in a phased approach which included, first the compilation of existing functions which were logical candidates for display on the MMD and the identification of new sensors required to provide the necessary additional information which is not presently available to the pilot. The second phase involved the definition of what data should be displayed and during which flight modes it should be available. Priorities for display of the information were established as a function of flight modes and the data were identified as to class such as advisory, warning, caution, or data which is only displayed when called up by the pilot. The priorities and classification of data varies in some cases with the flight mode of the aircraft. The last study phase included a definition of integration requirements for the MMD in the A-7E. Both the hardware integration requirements and the MMD related software requirements were defined. The production TC-2A computer in the A-7E has adequate reserve to perform the processing computations required for the MMD. A simple interface box will provide the organization and conversion of the A-7E sensor signals into the format required for inputs to the computer. This box will provide memory for storage of certain data as required prior to call-up for display. A Human Factors analysis was performed to help develop the criteria for selection of the data for display on the MMD and to define the man-machine interface requirements for the MMD installation.

The MMD Study results presented herein indicates that it is quite feasible to use an integrated display concept in the A-7E aircraft. This study only addressed the MMD which is one of five master displays in the AIDS concept. A similar feasibility study is recommended for the full AIDS integration in an A-7 type aircraft to identify the requirements and special aircraft integration constraints which must be considered in the installation of the integrated display concept in a tactical aircraft.

2.0 MMD CANDIDATE SELECTION

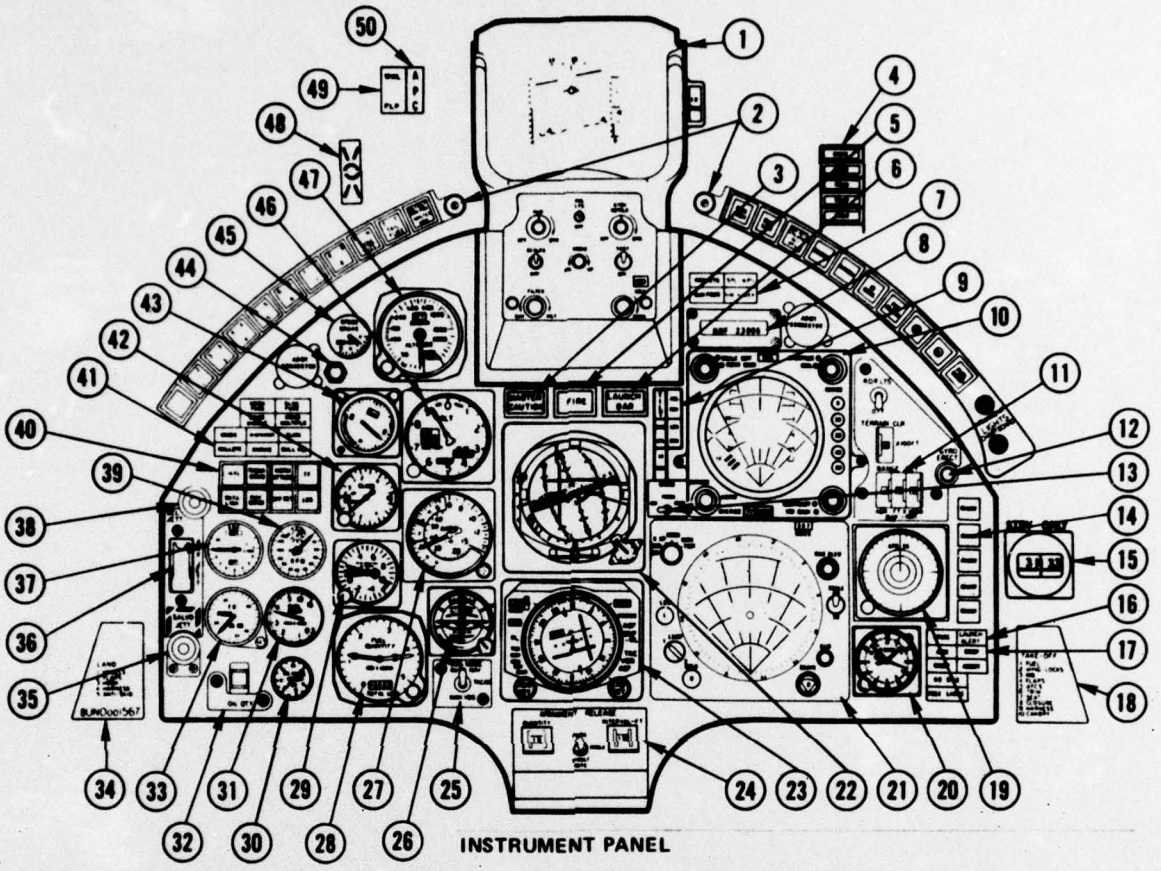
The A-7E aircraft was chosen for this MMD applications study because it has a representative high density conventional cockpit and has a highly integrated navigation/weapons delivery system (NWDS) and heads up display which is representative of the AIDS technology. The NWDS hardware and technology provide a natural point of departure for the MMD configuration studies and hardware interface definition. There are approximately 100 indicator lights in the A-7 cockpit approximately 50 of which are candidates for the MMD. The remainder are either engine related indicator lights which would be displayed on the EMD or armament related which, it is assumed, shall appear on an integrated armament control/display panel. There are also many individual indicators such as fuel status, hydraulic system status, aerodynamic controls etc. which are candidates for the MMD.

2.1 Existing A-7E Cockpit Instruments

The pilots instruments and indicators currently in the A-7E cockpit are, for the most part, dedicated to individual functions and operations. As new capabilities are added to the aircraft for which new indicators are required the competition for the prime cockpit space becomes more and more critical. This situation is typical of most operational aircraft today. All of the instruments and indicators need to be located in positions which are readily visible to the pilot at the time that function is important to him but, obviously, there are limits to optimizing the location of dedicated individual indicators.

The current layout of the instruments and controls in the A-7E cockpit are shown in Figures 2-1 through 2-3. These figures depict the locations of the controls and instruments in the instrument panel as well as the left hand and right hand consoles.

The pilots flight instruments are functionally grouped on the A-7E cockpit instrument panel (see Figure 2-1) with the navigation and flight instruments in the center, the system monitoring (fuel quantity, oil pressure, turbine outlet pressure and temperature) instruments are grouped in



INSTRUMENT PANEL

1. HEAD-UP DISPLAY
2. ARMAMENT SELECT SWITCHES
3. MASTER CAUTION LIGHT
4. RHAW THREAT LIGHTS
5. FIRE WARNING LIGHT
6. LAUNCH BAR LIGHT
7. ARMAMENT ADVISORY LIGHTS
8. UHF REMOTE CHANNEL INDICATOR
9. DATA LINK DISCRETE LIGHTS
10. RADAR SCOPE
11. RADAR RANGE SET CONTROLS
12. GYRO ERECT SWITCH
13. SHRIKE SWITCH
14. RHAW WARNING LIGHTS
15. STANDBY COMPASS
16. LAUNCH ALERT WARNING LIGHT
17. DATA LINK DISCRETE LIGHTS
18. TAKEOFF CHECKLIST
19. ECM THREAT ANALYZER
20. CLOCK
21. PROJECTED MAP DISPLAY
22. ATTITUDE DIRECTOR INDICATOR
23. HORIZONTAL SITUATION INDICATOR
24. ARMAMENT RELEASE PANEL
25. HEADING MODE SWITCH
26. STANDBY ATTITUDE INDICATOR
27. AIRSPEED INDICATOR
28. FUEL QUANTITY INDICATOR
29. ACCELEROMETER
30. OIL PRESSURE INDICATOR
31. FUEL FLOW INDICATOR
32. OIL QUANTITY INDICATOR
33. TURBINE OUTLET PRESSURE INDICATOR
34. LANDING CHECKLIST
35. SALVO JETTISON SWITCH
36. AUXILIARY JETTISON SWITCH
37. TURBINE OUTLET TEMPERATURE INDICATOR
38. SELECT JETTISON SWITCH
39. TACHOMETER
40. MASTER FUNCTION SELECTORS
41. ARMAMENT ADVISORY LIGHTS
42. VERTICAL VELOCITY INDICATOR
43. ANGLE-OF-ATTACK INDICATOR
44. RADAR ALTIMETER LOW ALTITUDE WARNING LIGHT
45. SPEED BRAKE POSITION INDICATOR
46. SERVOED ALTIMETER
47. RADAR ALTIMETER
48. APPROACH INDEXER
49. WHEELS/FLAPS WARNING LIGHTS
50. APPROACH POWER CONTROL WARNING LIGHT

Figure 2-1 Cockpit Instrument Panel

LH CONSOLE ARRANGEMENT

1. AFCS TRIM INDICATORS
2. EMERGENCY POWER PACKAGE HANDLE
3. LEADING EDGE FLAPS POSITION INDICATOR
4. TRAILING EDGE FLAPS POSITION INDICATOR
5. LANDING GEAR POSITION INDICATORS
6. LANDING GEAR CONTROL HANDLE
7. GENERATOR INDICATOR
8. BULLPUP CONTROL
9. CATAPULT GRIP
10. EMERGENCY BRAKE CONTROL
11. THROTTLE CONTROL
12. RUDDER TRIM CONTROL
13. RADAR CONTROL PANEL
14. UHF CONTROL PANEL
15. FUZE FUNCTION CONTROL
16. DATA LINK
17. SPEECH SECURITY
18. UHF/ADF RADIO
19. OXYGEN QUANTITY INDICATOR
20. PILOT SERVICES PANEL
21. SUIT TEMPERATURE CONTROL
22. AUDIO CONTROL
23. IFF CONTROL PANEL
24. FLAPS CONTROL
25. AUTOPILOT CONTROL PANEL
26. APC
27. ANTISKID CONTROL
28. AIR REFUELING SWITCH
29. PITOT ANTI-ICE SWITCH
30. FUEL MANAGEMENT CONTROL PANEL
31. TRIM POSITION INDICATOR
32. AFCS TEST CONTROL
33. PITCH AND ROLL TRIM SWITCHES
34. CANOPY JETTISON HANDLE
35. DECOY SWITCH

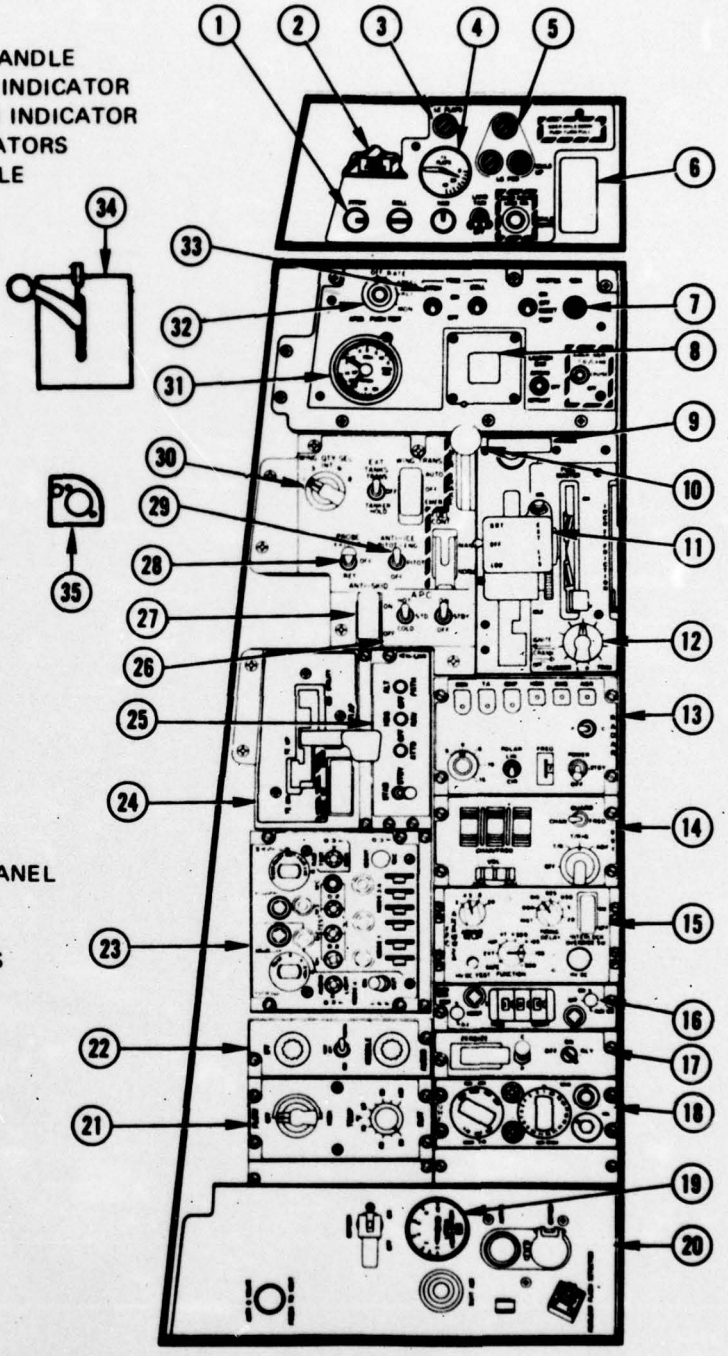
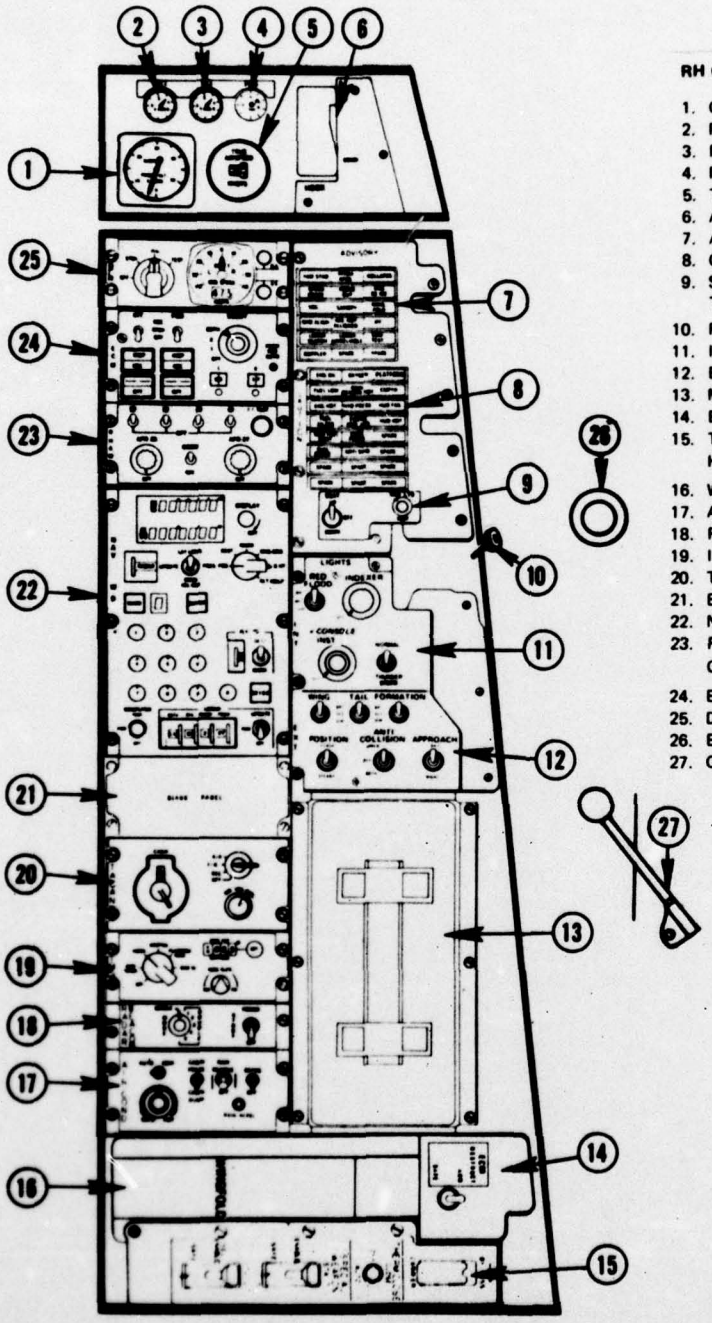


Figure 2-2 Left Hand Console



RH CONSOLE ARRANGEMENT

1. CABIN PRESSURE ALT
2. PC-1 PRESSURE INDICATOR
3. PC-2 PRESSURE INDICATOR
4. PC-3 PRESSURE INDICATOR
5. TRUE AIRSPEED INDICATOR
6. ARRESTING HOOK CONTROL
7. ADVISORY LIGHTS
8. CAUTION LIGHTS
9. SEAT AND INDICATOR LIGHT TEST SWITCHES
10. FOOT AIR VENT CONTROL
11. INTERIOR LIGHTS CONTROL PANEL
12. EXTERIOR LIGHTS CONTROL PANEL
13. MAP CASE
14. ECM DESTRUCT
15. THERMAL CLOSURE,SPECIAL WEAPONS, HOOK BYPASS
16. WINGFOLD
17. AIR-CONDITIONING CONTROL PANEL
18. RADAR BEACON CONTROL
19. IMS CONTROL PANEL
20. TACAN CONTROL PANEL
21. BLANK PANEL
22. NAV/WEAPON COMPUTER PANEL
23. RADAR HOMING AND WARNING CONTROL PANEL
24. ECM CONTROL PANEL
25. DOPPLER RADAR CONTROL PANEL
26. EMERGENCY VENT AIR CONTROL
27. CANOPY LOCK HANDLE

Figure 2-3 Right Hand Console

the lower left hand side of the panel and the armament controls and indicators are located on the lower center and upper left hand side. Caution and Warning functions and advisories are on the lower right hand side and on the cowl across the top of the instrument panel. The left hand console shown in Figure 2-2 contains controls and indicators for the automatic flight control system (AFCS), landing gear, emergency power package, autopilot, engine, fuel, flaps, UHF communications (IFF), radar, fuze control, intercommunications, oxygen, air refueling, suit vent and pilot services. The right hand console contains the interior and exterior lighting controls, caution and advisory annunciators, and the controls and indicators for hydraulic pressure, arresting hook, doppler radar, tactical computer, TACAN, ECM, Inertial Measurement Set (IMS), radar beacon and environmental and wingfold systems.

2.2 Candidates for Display on MMD

The main purpose of the AIDS is to improve the pilots efficiency by simplifying his work load during critical mission modes. This is to be accomplished with the integrated controls and display philosophy of presenting all the information to the pilot on five master display sets. Most of the aircraft general flight information, warning and advisory information and system status data are primary candidates for integration into the MMD. The key to successfully mechanizing the MMD is in the selection of the data for the display, determination of when certain data is displayed, and the determination of how the data is selected whether by priority, by flight mode, or called up by the pilot. Another important consideration is to assure the data being displayed is pertinent, timely, and self-explanatory and the display is not cluttered with information not relevant to the pilots immediate needs.

2.2.1 Criteria for Selection of Functions

The functions chosen for display on the MMD were those that met the criterion described herein and those that provided the pilot with certain warning, caution, advisory and auxiliary data currently presented by a multitude of dedicated instruments. The criteria used in the

selection of candidate MMD information include the following:

a. Criticality of information to be displayed on the MMD.
b. Usefulness of displayed information to the pilot.
c. Sensor requirements and availability:
   - o The status of all electronic devices can be inputs to the display.
   - o The status of many mechanical items (those whose positions are read from micro-switches or potentiometers) can be inputs to the MMD.
d. Tradeoff between presenting the information on the MMD or by conventional means.

Priorities must be placed upon the information to be displayed in order to make maximum use of the display. If the MMD replaces other cockpit displays, it should present information to the pilot in a more usable format. The pilot must be able to obtain the desired information from the display with a minimum of effort. For an abnormal or emergency indication, the problem and its solution should be presented automatically to the pilot. If more than one anomaly occur within the same time frame, the display should present the most critical one first. The NATOPS Flight Manual for the A-7E (NAVAIR 01-45AAE-1) was used as a starting point in determining the display priorities. Test pilots and engineering specialists on the various aircraft systems were also contacted to help establish the priorities with respect to flight modes for the displayed data. The data are classified as warnings, cautions, advisories and call-up functions, where warnings take priority over cautions and cautions over advisories. The MMD does not include certain functions that would more appropriately be displayed on one of the other AIDS displays. For example, most engine functions were considered more appropriate for display on an Engine Management Display (EMD). Weapon inventory and delivery information was also omitted from the MMD and designated for readout on an integrated weapons management display system.

Functions chosen for display on the MMD must be easily adaptable to an alphanumeric display system so that the information is easily read

and understood. Functions whose values change very rapidly or where time history of the readings are important are not desirable as MMD candidates. Another major consideration was the effect on pilot workload, especially during critical mission segments such as weapon delivery and final approach for landing. If an increase in pilot workload was shown to be attributed to the MMD message content, then that function was eliminated from further consideration as a candidate. Likewise, if placing a function on the MMD would result in a possible compromise of safety or delay in presenting critical information to the pilot such as the "master caution" indication, then those functions were not assigned exclusively to the MMD even though explanatory information for these critical functions may have been assigned. Further discussion concerning pilot interface and workload relative to the incorporation of an MMD in the A-7E are contained in section 4.1 - Pilot Interface.

2.2.2 Candidate MMD Functions

The NATOPS Flight Manual was used as the primary reference in the selection of the initial candidate functions for display on the MMD. These functions are included in Table 2-1 which lists all of the significant A-7E pilots instruments and indicators that are candidates for incorporation into the AIDS concept. The measurements listed in the matrix are grouped together as major system functions such as fuel system, electrical system, etc. These measurements were screened using the previouly mentioned selection criteria and those which appear to be the logical functions for display on the MMD are so noted on the matrix. The final selection of the MMD candidates was made through an integrated effort of representatives from each of the pertinent subsystem engineering disciplines as well as from the Pilot's Staff, Field Engineering, Safety, and Human Engineering. NADC personnel also reviewed the list and made suggestions which were incorporated. Also shown in the matrix of Table 2-1 are the various categories of flight modes which influence the type message or the priority of the message depending on its criticality. The methods of handling a message will not necessarily be the same for all flight modes. As seen in Table 2-1 some messages such as "wheels/flaps" would be considered as a warning priority in take-off or landing modes and

TABLE 2-1 CANDIDATE A-7E FUNCTIONS FOR

SIGNIFICANT COCKPIT FUNCTIONS			FLIGHT MODES					
COMPONENT/ FUNCTION	FUNCTION DESCRIPTION	MMD CANDIDATE	PRE-FLIGHT	TAKE OFF	CLIMB	CRUISE	IN-FLT REFUEL	ATTA APPRO
ENGINE TF41								
OIL QUANTITY	FULL NORMAL, 1/2, LOW							
TURB OUT PRESS	INCHES OF MERCURY	X	W	W	CU	CU	CU	CU
TURB OUT TEMP	TEMPERATURE IN °C							
TACHOMETER	SPEED IN % RPM							
FUEL FLOW	MASS RATE IN LBS/HR.							
OIL PRESSURE	PRESSURE IN PSI							
ENGINE OIL	OIL QTY, PRESS, OR FLOW LOW	X	C	C	C	C	C	C
ENGINE HOT	TEMP OVER 620°C	X	C	C	C	C	C	C
MAN FUEL CONTR	FUEL SW IS IN MAN POSITION							
MAIN FUEL PUMP	FAILURE IN HI PRESS FUEL PUMP							
FUEL BOOST 1	ENG DRIVEN BOOST PUMP FAILURE							
FUEL BOOST 2	LOW PRESS FUEL PUMP FAILURE							
FUEL SYSTEM								
FUEL QUANTITY	FUS TK, TRANS TK & TOT QTY	X	CU	CU	CU	CU	CU	CU
FUEL LOW	FUEL <1350 LB.(<4000 LB T/O)	X	C	C	C	C	C	C
WING TANK PRESS	OVER PRESS IN WING TANK							
GALLONS DELIV	QTY FUEL DEL TO REC A/C							
DUMP	FUEL BEING DUMPED OR TRANS							
DROGUE POSITION	DROGUE EXT, ENGA, RET							
STATION SELECT	FOR TANKER STORE OR JETTISON							
PROBE OUT	PROBE NOT LOCKED IN POS							
ELECT. SYSTEM								
MASTER GEN OUT	GENERATOR OUTPUT	X	CU	CU	CU	CU	CU	CU
MASTER GEN	GEN OUT NEAR TOL LIMITS	X	C	C	C	C	C	C
HYDRAULIC SYST								
HYDRAULIC PRESS	PC-1, 2 OR 3 PRESS < 1500 PSI	X	C	C	C	C	C	C
PRESSURE,PSI	PC-1, 2, 3 SYST PRESS	X	CU	CU	CU	CU	CU	CU
EMER HYD ISO	EMER ACCUM VALVE OPEN							
FLT & TRIM SYS								
ROLL TRIM POS	ROLL POS 13°LFT - 13°RT	X	CU	CU	CU	CU	CU	CU
PITCH TRIM POS	PITCH POS 0-15° PITCH	X	CU	CU	CU	CU	CU	CU
STALL	RUD PEDAL SHAKER, AOA ≥ 20.5							
FLAP SYSTEM								
TRAIL EDGE POS	POSITION 0°-40°	X	CU	CU	CU	CU	CU	CU
LEAD EDGE POS	UP, DOWN, IN TRANSIT, UNLOCKED	X	A	A	A	A	A	A
WHEELS/FLAPS*	WHLS/FLAPS BOTH NOT UP OR DN	X	A	W	C	C	C	C

* Shown also under Landing Gear

NDIDATE A-7E FUNCTIONS FOR INTEGRATED DISPLAYS

FLIGHT MODES							SIGNAL CLASSIFICATION			
	IN-FLT	ATTACK ON TARGET				POST-	TYPE OF SIGNAL		SENSOR	
CRUISE	REFUEL	APPROACH	EGRESS	DESCEND	LANDING	FLIGHT	ANALOG	DISCRETE	EXISTING	PROPOSED
CU	CU	CU	CU	CU	CU	CU	X		X	
C	C	C	C	C	C	C		X	X	
C	C	C	C	C	C	C		X	X	
CU	CU	CU	CU	CU	CU	CU	X		X	
C	C	C	C	C	C	A		X(2)	X	X
CU	CU	CU	CU	CU	CU	CU	X			X
C	C	C	C	C	C	A				SOFTWARE
C	C	C	C	C	C	A		X(3)	X(3)	
CU	CU	CU	CU	CU	CU	CU	X(3)		X(3)	
CU	CU	CU	CU	CU	CU	CU	X		X	
CU	CU	CU	CU	CU	CU	CU	X		X	
CU	CU	CU	CU	CU	CU	CU	X		X	
A	A	A	A	A	A	A		X	X	
C	C	C	C	C	W	A		X	X	

N/A = NOT APPLICABLE
CU = CALL-UP FUNCTION
A = ADVISORY NOTICE
C = CAUTION CONDITION
W = WARNING CONDITION

TABLE 2-1 CANDIDATE A-7E FUNCTIONS

SIGNIFICANT COCKPIT FUNCTIONS			FLIGHT MODE					
COMPONENT/ FUNCTION	FUNCTION DESCRIPTION	MMD CANDIDATE	PRE-FLIGHT	TAKE OFF	CLIMB	CRUISE	IN-FLT REFUEL	AT AR
AFCS								
ACTUATOR POS	PITCH, ROLL, YAW ACTUATOR POS	X	CU	CU	CU	CU	CU	
YAW STAB	DISENGA OR YAW SW NOT IN STAB	X	A	A	A	A	A	
PITCH AFCS	DISENGAGED	X	A	A	A	A	A	
ROLL AFCS	DISENGAGED	X	A	A	A	A	A	
SPEED BRAKE								
POS INDICATOR	CLO(0°) TO FULLY OPEN(60°)	X	CU	CU	CU	CU	CU	
SPEED BRAKE	SPEED BRAKE NOT CLOSED	X	A	A	A	A	A	
LANDING GEAR								
LG POSITION	UP-DN-IN TRANSIT	X	CU	CU	CU	CU	CU	
HANDLE WARNING	NOT LOCKED IN POSITION	X	W	W	C	C	C	
WHEELS/FLAPS*	BOTH NOT UP OR DOWN	X	A	W	C	C	C	
NOSE GEAR STEE	NOSE GEAR STEERING ENGAGED	X	A	A	N/A	N/A	N/A	
WHEEL BRAKES								
ANTI-SKID	MALFUNCTION, SWITCH TO MANUAL	X	C	C	N/A	N/A	N/A	
TAIL HOOK								
HOOK HNDL WARN	HOOK NOT IN SELECTED POSITION	X	A	A	N/A	N/A	N/A	
CATAPULT SYS								
LAUNCH BAR	SWITCH IN EXTEND OR MALFUNCT	X	W	W	N/A	N/A	N/A	
WINGFOLD SYS								
WINGFOLD	LOCK LEVER NOT FULLY LOWERED	X	A	A	A	A	A	
FIRE DETECT SYS								
FIRE	ENGINE COMP FIRE OR OVERHEAT	X	W	W	W	W	W	
FIRE	WHEEL WELL FIRE	X	W	W	W	W	W	
CANOPY								
CANOPY	CANOPY UNLOCKED	X	A	A	A	A	A	
AIR CONDITION								
RAIN REMOVE HOT	DUCT TEMP EXCEEDING 290°F	X	C	C	C	C	C	
COCKPIT PRESS	PRESS MALFUNCTION							
COCKPIT TEMP	TEMP MALFUNCTION							
MASTER CAUTION								
CAUTION	MALFUNCTION OR ABNORM COND	X	C	C	C	C	C	

* Shown also under Flaps System

CANDIDATE A-7E FUNCTIONS FOR INTEGRATED DISPLAYS

FLIGHT MODES								SIGNAL CLASSIFICATION			
		IN-FLT	ATTACK ON TARGET				POST-	TYPE OF SIGNAL		SENSOR	
LIMB	CRUISE	REFUEL	APPROACH	EGRESS	DESCEND	LANDING	FLIGHT	ANALOG	DISCRETE	EXISTING	PROPOSED
CU	CU	CU	CU	CU	CU	CU	CU	X(3)		X(3)	
A	A	A	A	A	A	A	A		X(3)	X	X(2)
A	A	A	A	A	A	A	A		X	X	
A	A	A	A	A	A	A	A		X	X	
CU	CU	CU	CU	CU	CU	CU	CU	X		X	
A	A	A	A	A	A	A	A		X	X	
CU	CU	CU	CU	CU	CU	CU	CU		X	X	
C	C	C	C	C	C	W	W		X	X	
C	C	C	C	C	C	W	A		X	X	
N/A	N/A	N/A	N/A	N/A	N/A	A	A		X	X	
N/A	N/A	N/A	N/A	N/A	N/A	C	A		X	X	
N/A	N/A	N/A	N/A	N/A	N/A	W	A		X	X	
N/A	N/A	N/A	N/A	N/A	N/A	W	A		X	X	
A	A	A	A	A	A	A	A		X	X	
W	W	W	W	W	W	W	W		X	X	
W	W	W	W	W	W	W	W		X		X
A	A	A	A	A	A	A	A		X	X	
C	C	C	C	C	C	C	C		X	X	
C	C	C	C	C	C	C	C		X	X	

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TABLE 2-1 CANDIDATE A-7E FUNCTIONS FO

SIGNIFICANT COCKPIT FUNCTIONS			FLIGHT MODES					
COMPONENT/ FUNCTION	FUNCTION DESCRIPTION	MMD CANDIDATE	PRE-FLIGHT	TAKE OFF	CLIMB	CRUISE	IN-FLT REFUEL	ATTAC APPRO
OXYGEN SYSTEM								
QUANTITY	QTY LIQUID OXYGEN(LITERS)	X	CU	CU	CU	CU	CU	CU
OXYGEN	≤1 LITER OR REG PRESS ≤ 42 PSI	X	C	C	C	C	C	C
EMERG OXY PRESS	PRESS IN EMERG OXY BOTTLE							
APPRO PWR CONTR								
APPRO PWR CONTR	SYS IN STBY OR DISENGAGED	X	N/A	N/A	N/A	N/A	N/A	N/A
ANGLE OF ATTACK								
ANGLE OF ATTACK	RANGE OF 0 TO 30 UNITS	X	CU	CU	CU	CU	CU	CU
FLIGHT INST								
NORM ACCEL	-5 TO 10 G's							
VERT VELOCITY	ACENT/DESCENT RATE 0-6000 FPM							
ALTITUDE	WITHIN 100 FEET							
AIR SPEED/MACH	80-650 KNOTS/0.4-2 MACH NO.							
BAROMETER	ALTITUDE IN INCHES OF Hg							
STBY ATTITUDE	360° ROLL; ±82° PITCH; PWR FLG							
TRUE AIRSPEED	TRUE AIRSPD; ADC INOP FLAG							
STBY COMPASS	360° AZIMUTH							
STBY FLG ON ALT	SERVO SYS MALFUNCT; PNEU OPER							
TACT COMPUTER								
COMPUTER	COMPUTER FAILURE	X	A	A	A	C	A	C
IMS								
LATITUDE IND	INSERT LAT IN MAG VARIATION							
GND ALIGN	MODE SW IN GND ALIGN							
IMS NOT ALIGN	IMS NOT ALIGN; IMS/DPLR DIFF	X	A	A	A	A	A	A
PLATFORM	IMS SYSTEM FAILURE	X	C	C	C	C	C	C
DOPPLER RADAR								
DOPPLER	UNRELIABLE INFO	X	N/A	A	A	A	A	A
DRIFT ANGLE	DRIFT ANGLE 40° LFT -40° RT							
GROUND SPEED	GROUND SPEED 0-999 KNOTS							
AIR DATA CMPTR								
ADC	FAILURE IN ADC SYST	X	A	A	A	A	A	C
FWD LOOK RADAR								
FAIL	RADAR FAIL, CLIMB COMD IN TF	X	A	N/A	A	A	N/A	C
RANGE	OPERATING RANGES							
TV/SHRIKE	TV OR SHRIKE DISPLAY AVAIL							
IN RANGE	FLR IN AGR & LOCKED ON TARGET							

CANDIDATE A-7E FUNCTIONS FOR INTEGRATED DISPLAYS

FLIGHT MODES								SIGNAL CLASSIFICATION			
			ATTACK ON TARGET					TYPE OF SIGNAL		SENSOR	
LIMB	CRUISE	IN-FLT REFUEL	APPROACH	EGRESS	DESCEND	LANDING	POST-FLIGHT	ANALOG	DISCRETE	EXISTING	PROPOSED
CU C	CU C	CU C	CU C	CU C	CU C	CU C	CU A	X	X	X X	
N/A	N/A	N/A	N/A	N/A	N/A	W	A		X(2)	X	X
CU	CU	CU	CU	CU	CU	CU	CU	X		X	
A	C	A	C	C	A	A	A		X	X	
A C	A C	A C	A C	A C	A C	A C	A A		X X	X X	
A	A	A	A	A	A	A	N/A		X	X	
A	A	A	C	C	A	A	A		X	X	
A	A	N/A	C	C	C	N/A	A		X	X	

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TABLE 2-1 CANDIDATE A-7E FUNCTIONS FOR I

SIGNIFICANT COCKPIT FUNCTIONS			FLIGHT MODES					
COMPONENT/ FUNCTION	FUNCTION DESCRIPTION	MMD CANDIDATE	PRE-FLIGHT	TAKE OFF	CLIMB	CRUISE	IN-FLT REFUEL	ATTAC APPRO
RADAR ALT								
ALTITUDE	ALT 0-5000 FT & OFF FLAG							
SELF TEST	SYSTEM SELF TEST							
LOW ALT WARN	ALT BELOW SEL INDEX MARK	X	A	N/A	C	W	N/A	W
SYS MONITOR	SYSTEM MALFUNCTION	X	A	A	A	A	A	A
HUD								
HUD FAIL	HUD FAILURE	X	A	C	C	C	C	C
MILS	DEPRESS ANGLE OF STBY RETICLE							
HUD HOT	OVERHEAT CONDITION	X	C	C	C	C	C	C
PULL-UP CMD	FLASHING X ON HUD							
WARNING IND	LINES ON HUD							
PROJ MAP DISPL								
MILES	MILES TO DESTINATION							
FAIL	FLAG-PMDS FAILURE	X	A	N/A	A	A	N/A	A
DECENTER	A/C POS AT BOTTOM IN NORM							
HOLD	HOLDS MAPS IN CURRENT POS							
DATA	TF 41 ENGINE PROCEDURES							
ADI								
OFF FLAG	FAIL; IMS UNREADABLE	X	A	C	C	C	C	C
VERT PT ALARM	FLAG-UNREADABLE SIGNALS							
HORIZ PT ALARM	FLAG-UNREADABLE SIGNALS							
DISPL PT ALARM	FLAG-UNREADABLE SIGNALS							
HSI								
COURSE	COURSE SELECTED (UP TO 360°)							
HEADING	HEADING SELECTED (UP TO 360°)							
MILES	DIST TO DESTINATION; TO TACAN							
DISTANCE FLAG	DIST SIG UNREADABLE							
TO-FROM	INDICATES TO OR FROM TACAN							
ADF	HDG MODE IN TACAN OR MAN							
BEARING PT #2	BEARING TO SEL ADF							
TAC	HDG MODE SW IN TACAN OR MAN							
BEARING PT #1	BRG TO TAC CMPTR DESTINATION							
MODE	MODE SELECT MONITOR	X	CU	CU	CU	CU	CU	CU
CRSE DEV ALARM	INADEQUATE SIG ON #1 POINTER	X	N/A	N/A	A	A	A	A
OFF FLAG	PWR OR INDICATOR FAIL	X	A	A	A	A	A	A
APX-72								
IFF	MODE 4 NOT REPLIED TO INTERO							
MODE 4 REPLY	VALID MODE 4 REPLIES							
TEST	PROPER RCVR-XMTR RESPONSE							

CANDIDATE A-7E FUNCTIONS FOR INTEGRATED DISPLAYS

FLIGHT MODES								SIGNAL CLASSIFICATION			
			ATTACK ON TARGET					TYPE OF SIGNAL		SENSOR	
CLIMB	CRUISE	IN-FLT REFUEL	APPROACH	EGRESS	DESCENT	LANDING	POST-FLIGHT	ANALOG	DISCRETE	EXISTING	PROPOSED
C	W	N/A	W	W	W	W	N/A		X	X	
A	A	A	A	A	A	A	A		X		X
C	C	C	C	C	C	C	A		X	X	
C	C	C	C	C	C	C	C		X	X	
A	A	N/A	A	A	A	N/A	A		X	X	
C	C	C	C	C	C	C	A		X	X	
CU	CU	CU	CU	CU	CU	CU	CU		X		X
A	A	A	A	A	A	N/A	N/A		X	X	
A	A	A	A	A	A	A	A		X	X	

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TABLE 2-1 CANDIDATE A-7E FUNCTIONS

SIGNIFICANT COCKPIT FUNCTIONS			FLIGHT MOD					
COMPONENT/ FUNCTION	FUNCTION DESCRIPTION	MMD CANDIDATE	PRE-FLIGHT	TAKE OFF	CLIMB	CRUISE	IN-FLT REFUEL	A/ A
ARC-51								
UHF FREQ	REMOTE INDICATOR (COUNTER)							
GUARD	"GUARD" IN WINDOW WHEN G SEL							
TACAN								
GO	SATISFACTORY SELF TEST							
NO-GO	UNSATISFACTORY SELF TEST							
ACLS								
TILT	END OF MESSAGE OR FAILURE							
ACLS	AFCS SYS DECOUPLED							
CMD CTL	RADAR LK & INFO TO DATA LINK							
ACL RDY	RADAR LK & READY TO CONTR A/C							
IO SEC	IND MOTION COMP INCLUDED							
LDG CHK	PILOT TO MAKE PRELAND CHECK							
WAVE OFF	DO NOT LAND							
NO MSG	DATA LINK ON BUT NO VALID DATA							
AN/ARA-63 IND	POWER ON ACLS							
HUD LDG	ACLS DATA ON HUD IN LDG MODE							
ADI LDG	ACLS DATA ON ADI IN LDG MODE							
AOA INDEXER	SLOW TO FAST IND FOR LDG APPRO							
ACLS TEST	TESTS FOR ACLS MALFUNCTION	X	A	N/A	N/A	N/A	N/A	

-1 CANDIDATE A-7E FUNCTIONS FOR INTEGRATED DISPLAYS

FLIGHT MODES								SIGNAL CLASSIFICATION			
			ATTACK ON TARGET					TYPE OF SIGNAL		SENSOR	
CLIMB	CRUISE	IN-FLT REFUEL	APPROACH	EGRESS	DESCEND	LANDING	POST-FLIGHT	ANALOG	DISCRETE	EXISTING	PROPOSED
N/A	N/A	N/A	N/A	N/A	A	A	A		X(2)	X	X

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a caution during other flight modes. The definitions of the classes of messages are similar to those defined in the NATOPS Flight Manual and are:

- o Warning - An emergency situation requiring immediate attention.
- o Caution - A condition which constitutes an impending emergency and will require actions in the near future.
- o Advisory - A situation that warrants the pilots attention but is not an emergency or caution nature.
- o Call-Up - These functions are displayed only when requested by the pilot and not automatically as are the first three categories.

As mentioned previously the matrix shown in Table 2-1 contains all of the significant signals displayed in the A-7E cockpit, however, entries are made in the flight mode columns for only the MMD candidates. The remaining functions are not expanded into the flight mode columns since these signals would more appropriately be displayed elsewhere, such as on an Engine Management, Vertical Situation, or Horizontal Situation Display. The flight modes shown in the matrix cover the major segments of a mission from pre-flight through post flight. Entries are made in the matrix flight mode columns for each function chosen for display on the MMD showing the relative importance of the function to the flight mode. The type of signal or sensor is also identified on the matrix. The sensor information shows whether the signal is analog or discrete and whether the information is available from an existing sensor or a new sensor is required. A justification for each of the recommended new sensors is given in paragraph 3.2.

The letter entries in the matrix are coded W for warnings, C for caution conditions, A for advisory statements, CU for information available for callup by the pilot, and NA for not applicable to roughly correspond to the warning, caution and advisory light system currently in the A-7E. Although the priority classifications of the entries closely correspond to those described in the NATOPS Flight Manual, there are some differences due to the MMD being a more versatile and more informative system than the lights and instruments currently used. The urgency of each situation depends, to a large extent, on the flight mode of the

aircraft which in turn determines the priority classification placed on the entries into the matrix. In addition to the use of the NATOPS manual in prioritizing the matrix entries, Vought staff pilots and various engineering systems specialists evaluated each of the situations as to their urgency in the various flight modes.

3.0 INFORMATION TO BE DISPLAYED

3.1 Data Requirements

The types of data to be displayed on the MMD will range from single line statements, such as subsystem status, to full page messages and tables of system status and check lists. Information pertaining to an emergency or an out of tolerance condition will be displayed automatically and other types of data will be available for callup by the pilot. When all systems are operating normally and the pilot has made no request for information, the display will remain blank except for possibly some constant test symbol to indicate that the MMD is on and functioning properly. Table 3-1 is a complete listing of candidate functions for the MMD and as such, serves as a quick reference list which defines the categories of information available to the pilot, as well as whether the information is displayed automatically or manually. An M in the table indicates a stored message is to be automatically displayed on the MMD for that particular function as a result of a warning or caution condition. The A and CU entries are the same as the symbols used in the matrix, Table 2-1, in that an A implies an advisory statement will automatically be displayed and a CU implies that the data for that function is available for call-up by the pilot. The Master Caution Function on the list of Table 3-1 currently interfaces with 17 caution signals in the A-7E (some of which would be displayed on an EMD). An asterisk preceeds each of the 11 MMD candidates that interface with this master caution function.

3.1.1 Messages

Any situation classified as an emergency requiring immediate attention constitutes a "warning" while conditions that constitute an impending emergency requiring pilot action are classified as a "caution". Either a warning or caution condition will cause a message to be displayed on the MMD. The message will consist of a heading stating the situation, followed by a set of instructions to aid the pilot in the steps he should take to possibly correct the malfunction. The message and its priority for a given malfunction may vary for the different flight modes. For

TABLE 3-1

TYPE OF DISPLAY FOR MMD FUNCTIONS

FUNCTION	TAKEOFF	INFLIGHT	LANDING
Turbine Outlet Pressure	M	CU	CU
* Engine Oil Low (Qty/Press)	M	M	M
* Engine Hot	M	M	M
Fuel Quantity	CU	CU	CU
* Fuel Low	M	M	M
Master Generator Output	CU	CU	CU
Generator Output Near Tol Limits	M	M	M
* Hydraulic Pressure Low (PC 1, 2, or 3)	M	M	M
Hydraulic Pressure (PC 1, 2, and 3)	CU	CU	CU
Roll Trim Position	CU	CU	CU
Pitch Trim Position	CU	CU	CU
Trailing Edge Flap Position	CU	CU	CU
Leading Edge Flap Position	A	A	A
Wheels/Flaps Warning	M	M	M
Pitch, Roll, Yaw Actuator Position	CU	CU	CU
Yaw Stab Disengaged	A	A	A
Pitch AFCS Disengaged	A	A	A
Roll AFCS Disengaged	A	A	A
Speed Brake Position	CU	CU	CU
Speed Brake Not Closed	A	M	M
Landing Gear Position	CU	CU	CU
Landing Gear Handle Warning	M	M	M
Nose Gear Steering Engaged	A	-	A
* Anti-Skid Malfunction	M	-	M
Tail Hook Warning	A	-	M
Launch Bar Malfunction	M	-	M
Wingfold Locklever Advisory	M	M	M
Fire Warning	M	M	M
Canopy Unlocked	A	M	M

M MESSAGE(For Warning or Caution)
A ADVISORY NOTICE
CU CALL-UP
* MASTER CAUTION FUNCTIONS

TABLE 3-1 (Continued)

TYPE OF DISPLAY FOR MMD FUNCTIONS

FUNCTION	TAKEOFF	INFLIGHT	LANDING
* Rain Remove Duct Hot	M	M	M
Master Caution	(See Foot Note *)		
Liquid Oxygen Quantity	CU	CU	CU
* Oxygen Low	M	M	M
Approach Power Control Warning	-	-	M
Angle of Attack	CU	CU	CU
* Tactical Computer Failure	A	M	A
IMS Not Aligned	A	M	A
* IMS Platform Failure	M	M	M
Doppler Unreliable	A	M	A
Air Data Computer Failure	A	M	A
Forward Looking Radar Failure	-	M	A
Radar Altimeter Low Alt. Warn.	-	M	M
Radar Altimeter System Monitor	A	M	A
* HUD Failure	A	M	M
* HUD Hot	M	M	M
Projected Map Display Failure	-	M	-
Attitude Director Indicator Off	M	M	M
HSI Mode Select Monitor	CU	CU	CU
HSI Course Deviation Alarm	-	M	-
HSI Off Flag	A	M	A

M MESSAGE (For Warning or Caution)
A ADVISORY NOTICE
CU CALL-UP
* MASTER CAUTION FUNCTIONS

example, a malfunction in the landing gear system would have a different message and priority during the cruise segment of a mission than for the landing mode. Messages have been devised for each warning or caution shown in the matrix of Table 2-1. The messages that are automatically displayed on the MMD are shown in Tables 3-2 through 3-4. The messages are divided into categories corresponding to the three major flight modes of takeoff, inflight, and landing. The headings on each table are broad term, for example, in Table 3-2 "Takeoff" includes the pre-takeoff through climb columns in the matrix, while the flight segment Table 3-3 includes all flight modes from climb out to descent, and in Table 3-4 "Landing" includes the final phase of the descend column through the actual landing column in the matrix of Table 2-1.

3.1.2 Advisory Statements

Situations that warrant the attention of the pilot but are neither classified as an emergency or necessarily as an impending emergency for a given flight mode are termed an advisory. Most of the advisories are displayed as single line statements; however, there are a few that also have messages associated with them. For the single line statement advisory notices, the MMD would display for example, "PITCH AFCS DISENGAGED". An advisory for one flight mode may be a warning or a caution for another flight mode. For example, if there is an arresting hook malfunction, it would be programmed as an advisory for the takeoff mode and a warning for a carrier land situation. In establishing display priorities, the warning message would take display priority over a caution and cautions over advisories.

3.1.3 Checklists

Checklists for display on the MMD have been included as an aid to the pilot for pre-takeoff, takeoff, landing and postflight. An entire preflight checklists would be too long for practical display; therefore, only functions requiring status conformation prior to takeoff are included as representative of the preflight column on the matrix of Table 2-1. The checklists presented in Table 3-5 are in a format compatible with the

TABLE 3-2
MMD MESSAGE TABLE - TAKEOFF

Situation	Signal Monitored	MMD Message
Turbine Outlet Press Below Preset Value	Turbine Outlet Press	(Before T/O) 1) Turbine Press Low 2) Abort T/O
Engine Failure (Mode Sw T/O)	1) Turbine Outlet Press 2) Weight on LG 3) A/C in Motion (Airspeed must be 135 KIAS for Spinup of EPP)	Turbine Press Low (Before Becoming Airborne) 1) Abort or Eject (If Immediately After T/O and Airspeed < 135 KIAS) 1) Eject (If Immediately after T/O and Airspeed > 135 KIAS) 1) If Unable to Eject 2) Arrest Sink Rate 3) Land Straight Ahead 4) EPP - Extend 5) Salvo Jettison Stores 6) Throttle Off 7) Jettison Canopy 8) LG - Emerg Down 9) Emerg Flap Down
Engine Oil Qty, Press or Flow Low	1) Engine Oil Low (Oil Press < 12 PSI) 2) Weight on LG	Oil Low (Before T/O) 1) Abort T/O if Pos (After T/O Same as Inflight)
Engine Hot (Over 620°C)	1) Engine Temperature	Engine Hot 1) Abort T/O if Pos (If Airborne) 2) (Same as Inflight Engine Overheat)
Fuel Quantity below 4000 Lb	1) Fuel Quantity 4000 Lb Sensor	Fuel Low 1) Fuel Quantity < 4000 Lb 2) Refuel Soon as Pract.
Master Generator Output near Tol Limits	Main Power Buss	Voltage Low 1) Master Gen Output Near Tol Limits 2) Monitor Periodically

TABLE 3-2 (cont'd)
MMD MESSAGE TABLE - TAKEOFF

Situation	Signal Monitored	MMD Message
Hydraulic Press Low (< 1500 PSI)	1) Hydraulic Press 2) Weight on LG	Hydraulic Press Low 1) Abort T/O if Pos (If Airborne) 2) Monitor All PC Syst 3) (Same as Inflight- see Inflight PC Syst Failures)
Wheels/Flaps Not Both Down	1) LG Position 2) LE Flap Position 3) TE Flap Position	Flaps Not Lowered 1) If Unable to Lower Flaps - Abort T/O
Failure of Landing Gear to Indicate Up (After T/O and LG Handle in Whls Up)	1) Landing Gear Position 2) Handle Warning Signal	LG Not Up 1) Max Airspeed 220 KIAS 2) Gear Handle - Down (If LG Down) 3) Execute Norm Landing (If LG Not Down - See Appropriate LG Failure under Inflight Write-Up)
Anti-Skid Malfunction	1) Anti-Skid Caution Signal 2) LG Position	1) Anti-Skid Malfunct 2) Sw Anti-Skid Off
Launch Bar Fails to Retract (Carrier T/O)	1) Launch Bar Position	Launch Bar Not Ret 1) Emerg Gen Sw - T-O/Land 2) Extend EPP 3) Cabin Press - Dump 4) Mast Gen Sw - Off Reset (If Launch Bar Still Fails to Retract): 5) Flap Handle - ISO Util (If Launch Bar Retracts): 6) Land Gear - Emerg Down 7) Flaps - Emerg Down 8) Perform Norm Landing (If Still Fails to Retract): 6) Divert to Field 7) Arrest Cables - Remove 8) Normal Landing 9) Raise Before Taxi (If Unable to Divert): 6) Hook Down 7) Barricade Arrest

TABLE 3-2 (cont'd)
MMD MESSAGE TABLE - TAKEOFF

Situation	Signal Monitored	MMD Message
Wing Fold Lock Lever Not Fully Lowered	Lock Level Position	Wing Fold Lock Lever 1) Lock Lever Not Lowered 2) Check Lever Position 3) If Unable to Lower: 4) Abort T/O if Pos (If Airborne) 5) Avoid G Forces 6) Land Soon as Pract
Fire Detection Syst. Indicates Fire	1) Fire Detect System 2) Wt on LG 3) Aircraft Motion	Fire (Before Starting T/O) 1) Throttle - Off 2) Fuel Master Handle - Off 3) Abandon Aircraft (During T/O Roll, Field, Wt on LG) 1) Throttle - Off 2) Arrest Hook-Down 3) Apply Brakes 4) Transmit Intentions 5) Abandon Aircraft
Canopy Locking Malfunction	Canopy Lock Advisory Signal	(This Always Checked before T/O. If Unlock Signal Appears after Airborne, Message Same as Inflight)
Rain Remove Hot	1) Rain Remove Temperature 2) Wt. on LG	Rain Remove Hot (Before T/O) 1) Cycle Rain Remove Sw (If Overheat Persists) 2) Min Pract Pwr Setting 3) Abort T/O if Pos (If Airborne, Message Same as Inflight)
Master Caution	Master Caution Signal	(Master Caution will cause a message to appear on the MMD for the particular malfunction. For the 11 MMD Master Caution functions see Table 3-1).

TABLE 3-2 (contd)
MMD MESSAGE TABLE - TAKEOFF

Situation	Signal Monitored	MMD Message
Oxygen Low (≤1 Liter or ≤42 PSI at Reg)	Oxygen Press/Qty Caution Signal	1) Oxygen Low 2) Replenish before T/O
Tactical Computer Failure	Computer Fail Signal	Computer Fail
IMS Failure (ADI Off Flag)	IMS Fail Signal	1) IMS Failure 2) Use Stdby ADI
IMS Platform Failure	1) IMS Platform Fail Signal 2) ADI Off Flag Signal	1) IMS Failure (If Airborne, Message Same as Inflight)
HUD Failure	HUD Fail Signal	1) HUD Fail 2) Use Backup Functions
HUD Hot	HUD Hot Signal	1) HUD Hot 2) Turn Off until Absolutely Needed
ADI Off Flag	ADI Off Signal	1) ADI Off 2) Use Stdby ADI

TABLE 3-3
MMD MESSAGE TABLE - INFLIGHT

Situation	Signal Monitored	MMD Message
Engine Oil Qty Press or Flow Low (Press<12 PSI)	Engine Oil Caution Signal	Engine Oil Low 1) Throttle - Min Pract 2) EPP - Extend 3) Avoid Power Changes 4) Avoid Acceleration 5) Land ASAP 6) Shut Down ASAP
Engine Hot (Temp > 620° C But No Indication of Fire)	Engine Hot Signal	Engine Hot 1) Monitor TOT 2) Reduce Power (If Temp Remains over 620°) 3) Throttle - Idle (If Temp Remains over 620°) 4) If Altitude Permits: 5) Extend EPP 6) Emeg Gen Sw - Cruise 7) Throttle - Off 8) Perform Air Start 9) Land If Pos
Fuel Quantity Low (≤1350 Lb)	Fuel Low Signal	Fuel Low 1) Fuel Qty ≤ 1350 Lb 2) Refuel Soon as Pract
Master Generator Output Near Tol. Limits	Main Power Buss	Voltage Low 1) Master Gen Output Near Tol Limits 2) Monitor Periodically
Failure of All PC Systems	1) Hydraulic Pressure 2) All PC Syst Pressure (1500 PSI Min)	Hydraulic Fail 1) Extend EPP 2) Emerg Gen Sw - Off 3) Airspeed 200 KIAS Max (If EPP Restores Control) 4) Land ASAP 5) Flaps Up Recommended 6) Short Field Arrest (If EPP fails to Restore Control) 4) Eject

TABLE 3-3 (cont.)
MMD MESSAGE TABLE - INFLIGHT

Situation	Signal Monitored	MMD Message
Failure of PC1 or PC3	1) Hydraulic Pressure 2) All PC Syst Pressure (1500 PSI Min)	PC1 or PC3 Fail 1) Flap Handle - ISO Util 2) Monitr Remain PC Press 3) Antiskid Sw - Off 4) Land Soon as Pract
Failure of PC2	1) Hydraulic Pressure 2) All PC Syst. Pressure (1500 PSI Min)	PC2 Fail (Message same as for PC1 or PC3 Failure)
Failure of PC1 and PC2	1) Hydraulic Pressure 2) All PC Syst Pressure (1500 PSI Min)	PC1 and PC2 Fail 1) Falp Handle - ISO Util 2) Jettison Ext Stores 3) Max Airspeed 200 KIAS 4) Antiskid Sw - Off 5) Land Soon as Pract
Failure of PC1 and PC3	1) Hydraulic Pressure 2) All PC Syst Pressure (1500 PSI Min)	PC1 and PC3 Fail 1) Flap Handle - ISO Util 2) Jettison Ext Stores 3) Speed Brk Sw - Off 4) Max Airspeed 200 KIAS 5) Anti-Skid Sw - Off 6) Land Soon as Pract
Failure of PC2 and PC3	1) Hydraulic Pressure 2) All PC Syst. Pressure (1500 PSI Min)	PC2 and PC3 Fail 1) AFCS Enga Sw - Cont Aug 2) Jettison Ext Stores 3) Max Airspeed 200 KIAS 4) Flap Handle - ISO Util 5) Anti-Skid Sw - Off 6) Land Soon as Pract

TABLE 3-3 (cont.)
MMD MESSAGE TABLE - INFLIGHT

Situation	Signal Monitored	MMD Message
Flaps Not Up While Wheels Up	1) LG Position 2) LE Flap Position 3) TE Flap Position	Flaps Not Up 1) Max Airspeed 200 KIAS 2) Flap Handle - Check Up 3) Flaps - Cycle (If Malfunction Still Exists in LE Flaps or Both LE and TE) 4) Flap Handle - ISO Util 5) Flap Handle - Up 6) Return to Base 7) Avoid G Forces 8) Max Speed 200 KIAS (If Malfunction Still Exists in TE Flaps) 4) Flap Handle - Up 5) Return to Base 6) Avoid G Forces 7) Max Speed 220 KIAS
AFCS Malfunctions (Pitch or Roll)	1) AFCS Engage Sw Engaged 2) Yaw Stab Sw in Stab 3) Yaw, Pitch, and Roll Advisory Signals	Pitch or Roll Malfunct 1) Stick AFCS Sw - Actuate 2) AFCS Modes - Checked Off 3) Trim Aircraft Normally
(Yaw)		Yaw Malfunct 1) Yaw oscillates or has uncalled inputs 2) Yaw Stab Engage Sw - Off
Runaway Pitch Trim (Callup by Pilot)	None	Runaway Pitch Trim 1) Pitch and Roll Trim 2) Disconnect Sw - Off 2) Roll Trim - On 3) Land Soon as Pract
Inoperative Pitch Trim (Callup by Pilot)	None	Inop Pitch Trim 1) Pitch and Roll Trim Sw - Off Then On 2) Attempt Stick Trim Sw 3) If Stick Trim Fails to Respond - 4) AFCS Engage Sw - Attd 5) Land Soon as Pract.

TABLE 3-3 (Cont.)
MMD MESSAGE TABLE - INFLIGHT

Situation	Signal Monitored	MMD Message
Runaway or Inoperative Roll Trim (Callup by Pilot)	None	Roll Trim Malfunct 1) Roll and Pitch Trim Disco Sw - Off 2) Pitch Trim - On 3) AFCS Enga Sw - Cont Aug 4) Land Soon as Pract
Speed Brake Fails to Retract	1) Speed Brake Advisory Signal 2) Speed Brake Position	Spd Brk Not Ret 1) Cycle Spd Brk Sw to Clo 2) Max Speed 200 KIAS 3) Flap Handle - ISO Util 4) LG Handle - Whls Dn 5) Brk Should Close and LG Stay Up 6) Resume Cruise Speed
Landing Gear Not Locked in Up Position	1) LG Position 2) Handle Warning Signal	LG Not in Sel Pos 1) Max Airspeed 220 KIAS 2) Obtain Vis Ck if Pos 3) If Doors Not Fush with Fuselage 4) Gear Handle - Down 5) If Gear Down, Dont Cycle 6) Execute Norm Landing
Wing Fold Lock Lever Not Fully Lowered	Lock Lever Position	Wing Lock Lever 1) Check Level Position 2) If Unable to Lower: 3) Avoid G Forces 4) Land Soon as Pract
Engine Overheat or Engine Compartment Fire	1) Fire Detection Signal 2) Engine Hot Signal	Engine Hot or Fire 1) Throttle - Idle 2) Investigate Evidence 3) If No Fire Evident: 4) Return to Base 5) Use Minimum Power 3) If Fire Confirmed 4) Extend EPP 5) Throttle - Off 6) Air Restart if Pract 7) If Fire Persists - Eject

TABLE 3-3 (Cont.)
MMD MESSAGE TABLE - INFLIGHT

Situation	Signal Monitored	MMD Message
Wheel Well Fire	Wheelwell Fire Indicator Signal	Wheel Well Fire 1) Get Confirm If Pos 2) If Fire Exists 3) Eject
Electrical Fire (If electrical fire suspected and MMD still operative, Pilot can call-up this message. Not automatic.)	None	Electrical Fire 1) Mast Gen Sw - Off Reset 2) Emerg Sw - T/O Land 3) EPP - Extend 4) Nonessent Equip Off 5) If Fire Persists: 6) Emerg Gen Sw - Off 7) VFR Cond - Land ASAP 8) IFR Cond - Eject
Canopy Locking Malfunction	Canopy Advisory Signal	Canopy Lock Malfunct 1) Lower Visor 2) Ck Lock Lever 3) Reduce Speed 4) Lower Seat 5) Descend 6) Stow Loose Gear 7) Land Soon as Pract 8) Don't Use Spd Brake 9) Avoid Abrupt Maneuvers
Rain Remove Hot (>290°F)	Rain Remove Caution Signal	Rain Remove Hot 1) Retard Throttle 2) Rain Remove Sw - Cycle (If Overheat Persists) 3) Min Pract Pwr Setting 4) Return to Base
Master Caution	Master Caution Signal	(Master Caution will cause a message to appear on the MMD for the particular malfunction. For the 11 MMD Master Caution functions see Table 3-1.)
Oxygen Low (≤ 1 Liter)	Oxygen Low Signal	Oxygen Low 1) Oxygen ≤ 1 Liter 2) Descend to < 10K Ft 3) Monitor Oxy Qty 4) Land Soon as Pract

TABLE 3-3 (Cont.)
MMD Message Table - Inflight

Situation	Signal Monitored	MMD Message
Oxygen System Fails or Main Supply Empty	1) Oxygen Pressure/ Quantity	Oxygen Failure 1) Emerg Oxy Handle - Pull 2) If Mask Breathing Still Difficult - 3) Ck Mini Reg 4) Ck Hose Connections 5) Ck if Oxy Valve On 6) Ck Oxy Quantity 7) Emerg Dscnd to < 10K Ft 8) Remove Mask 9) Cockpit Press - Cab Dump 10) Emerg Vent - Open
Tact Computer Failure	Computer Fail Signal	Compute Fail
IMS Not Aligned or Difference Between IMS and Doppler	1) IMS Not Aligned Sig. 2) Doppler Fail Signal	IMS Not Aligned (If Doppler Operating Prop.) 1) Fly Strt and Level For 2 Min If Pos (If Still Not Aligned) 2) Sw IMS Off and Back On 3) Fly Strt and Level For 2 Min If Pos (If Still Not Aligned) 4) Use Stby Comp
IMS Platform Failure	1) IMS Platform Fail Signal 2) ADI Off Flag Signal	IMS Fail (If In TF Mode) 1) Climb Immediately 2) Turn IMS Pwr Off 3) IMS Pwr On 4) Fly Strt and Level For 2 Min If Pos (If Failure Still Exists) 5) Use Stby Comp & ADI (If Not in TF Mode, Step 1 Not Needed
Doppler Failure	Doppler Fail Signal	Doppler Failure 1) SW Doppler to Stby For 10 Sec & Back On (If Failure Still Exists) 2) IMS Automatically Pure Inertial

TABLE 3-3 (Cont.)
MMD MESSAGE TABLE - INFLIGHT

Situation	Signal Monitored	MMD Message
Air Data Computer Failure	ADC Advisory Signal If Caused by Icing } This Should Clear It }	Air Data Comp Fail 1) Use AOA as Airspd Ind 2) Dbl Dat/Pit Sw - Pitot (If Malfunction Still Exists After 60 Sec) 3) Descend Slowly To 8000 Ft Cabin Alt (Approx 23,000 Ft) 4) Open Emerg Air Vent 5) Cockpit Press-Cabin Dump 6) Use Cabin Alt Above 5K 7) Doppler for Gnd Spd
Forward Looking Radar Failure	FLR Fail Signal	FLR Failure (If in TF Mode) 1) Climb immediately 2) Ensure Target Alt Entered In Computer 3) Insure MSLP Entered In Computer 4) Range to Target Auto Using Aim Symbol & Alt
Radar Altimeter Low Alt Warning	Low Altitude Warn Sig	Altitude Low 1) Below Sel Alt Limit 2) Climb
Radar Altimeter System Malfunction	Radar Alt Continuous System Monitor	Altimeter Fail 1) Radar Alt Fail 2) Use Baro Alt and FLR
HUD Failure	HUD Fail Signal	HUD Failure (Cruise Mode) Attack Mode Only: 1) Turn on Stby Reticle 2) Calculate Pull-Up Mar 3) Stby Ret Depr Control Second Detent 4) Steer Till Stby Ret Overlies Target 5) Designate When Target In Center Stby Reticle 6) Hold Arm Rel Sw Dn on appro to Target

TABLE 3-3 (Cont.)
MMD MESSAGE TABLE - INFLIGHT

Situation	Signal Monitored	MMD Message
HUD Hot	HUD Hot Signal	HUD HOT 1) Turn HUD Off Until Absolutely Needed
PMDS Failure	PMDS Fail Flag Sig	PMDS Failure 1) Switch to Manual 2) Joystick Slews Display
ADI Off Flag	ADI Off Flag Signal	ADI Off (If in TF Mode 1) Climb Immediately 2) Use Stby ADI (If Not in TF Mode Step 1 Not Needed)
HSI Course Deviation Alarm (Effective Only with Mode Heading Sw in Tacan Pos)	1) HSI Course Dev Alarm Sig 2) Mode Select Monitor	HSI Devia Alarm 1) Tacan Brng Inadequate 2) Switch to Auto Nav or Man Heading
HSI Off Flag	HSI Off Flag Signal	HSI Off 1) Check HSI Off Sw 2) If HSI Failure - 3) Use HUD and Mag Comp

TABLE 3-4
MMD MESSAGE TABLE - LANDING

Situation	Signal Monitored	MMD Message
Engine Oil Qty, Press or Flow Low (Press < 12 PSI)	Engine Oil Caution Signal	Engine Oil Low 1) Throttle - Min Pract 2) Land ASAP 3) Shut Down ASAP
Engine Hot (TOT > 620°C But No Indication of Fire)	Engine Hot Signal	Engine Hot 1) Throttle - Min Pract 2) Monitor TOT if Pos 3) Land Soon as Pract
Fuel Quantity Low (≤ 1350 Lb)	Fuel Low Signal	Fuel Low 1) Fuel Qty ≤ 1350 Lb
Master Generator Near Tol Limits	Main Power Buss	(Message same as for inflight)
Hydraulic Pressure Low (< 1500 PSI)	Hydraulic Press Caution Signal	(Same as the 6 Inflight PC System Failure Messages)
Wheels Down But TE Flaps Not Down	1) TE Flap Position 2) PC2 Hydraulic Press 3) LG Position (Sense from up to down)	TE Flaps Not Down 1) Max Airspeed 220 KIAS (If PC2 Pressure Normal) 2) Force Flap Handle Agnst Dn Sw and Hold 3) Incr Spd to 210 KIAS 4) Cycle Flaps (If Malfunction Still Exists) 5) Flap Handle - ISO Util 6) Emerg Flap Sw - Emerg Dn (If Flaps Still Not Down Go to Flaps Up Landing) Ashore → 7) During Taxi: Flap Handle - Dn Carrier → 7) Before Raising Hook: Flap Handle - Dn

TABLE 3-4 (Cont)
MMD MESSAGE TABLE - LANDING

Situation	Signal Monitored	MMD Message
Assymmetrical Flap Condition	1) Flap Position	Assymmetric Flaps
	2) Landing Gear Position (sense from up to down)	1) Emerg Flap Sw - Emerg Dn 2) Check for Control 3) Land at 17.5 Units AOA (If Unable to Obtain Symmetrical Flaps) 4) Jettison Stores on Up-Flap Side as Needed
Flaps Up Landing, Ashore, Arrestment Feasible	Flap Position	Flaps Up Landing 1) Reduce Gross Wt 2) Straight-In Approach 3) AOA - 18 Units 4) Fly Flat Glideslope 5) Short or Midfld Arrest
Flaps Up Landing, Carrier	Flap Position	Flaps Up Land-Carrier 1) Divert (Rest of Message Same as for Ashore) 2) If Unable to Divert Barracade Arrest
Flaps Up Landing, Ashore, Arrestment not Feasible	Flap Position	Flaps Up Landing 1) Runway - Long, Dry 2) Max Headwind Component 3) Reduce Gross Wt 4) Straight-In Approach 5) AOA - 18 Units 6) Fly Flat Glideslope 7) Tch Dn Near Appro End 8) Throttle - Idle 9) Braking - Aerodynamic
Speed Brake Not Closed	1) Speed Brake Advisory Signal	Spd Brake not Closed
	2) Speed Brake Position	1) Spd Brake Pos is ____ (Position to be supplied)
Landing Gear Not Down When Down Position Selected	1) Landing Gear Warning Signal	Landing Gear Not Down
	2) Landing Gear Position	1) (Select Message for Particular LG Failure)

TABLE 3-4 (Cont)
MMD MESSAGE TABLE - LANDING

Situation	Signal Monitored	MMD Message
Landing with All Landing Gear Up (Field)	1) Landing Gear Position 2) Landing Gear Warning Signal	Landing With LG Up 1) Have Runway Foamed 2) Have Rollout Area Clr 3) Execute Min Sink Rate 4) At Touchdown: Throttle - Off 5) Fuel Master Handle - Off 6) Mast Gen Sw - Off Reset
Landing with All Landing Gear Up (Carrier)	1) Landing Gear Position 2) Landing Gear Warning Signal	Landing With LG Up 1) Divert if Possible 2) If Unable to Divert 3) Hook Down 4) Barricade Arrest
Landing with Nose Gear Up (Field)	1) Landing Gear Position 2) Landing Gear Warning Signal	Nose Gear Up Landing 1) Norm Land W/O Arrest 2) Have Rollout Area Clr 3) Near End of Pitch Control Throttle - Off 4) Fuel Master Handle - Off 5) Mast Gen Sw - Off Reset
Landing with One or Both Main Gear Up (Field)	1) Landing Gear Position 2) Landing Gear Warning Signal	Main Gear Up Landing 1) Have Runway Foamed 2) Avoid Hi Sink Rate 3) Short Field Arrest 4) Following Arrest: Throttle - Off 5) Fuel Master Handle - Off 6) Mast Gen Sw - Off Reset
Landing with One or Both Main Gear Up (Carrier)	1) Landing Gear Position 2) Landing Gear Warning Signal 3) Tail Hook Position	Main Gear Up Landing 1) Divert if Possible 2) If Unable to Divert 3) Extend Arrest Hook 4) Barricade Arrest

TABLE 3-4 (Cont)
MMD MESSAGE TABLE - LANDING

Situation	Signal Monitored	MMD Message
Landing with Nose Gear Up (Carrier)	1) Landing Gear Position 2) Landing Gear Warning Signal 3) Tail Hook Position	Nose Gear Up Landing 1) Divert if Possible 2) If Unable to Divert 3) Extend Arrest Hook 4) Avoid Hi Sink Rate 5) Barricade Arrest
Landing with One Main Gear and Nose Gear Up	1) Landing Gear Position 2) Landing Gear Warning Signal	(Same as for One or Both Main Gear Up)
Anti-Skid Malfunction	Anti-Skid Caution Signal	(Same as message for Takeoff)
Arresting Hook Up or Failed (Carrier)	1) Hook Handle Warning Signal 2) Hook Position	Arrest Hook Fail 1) Divert if Possible 2) If Unable to Divert 3) Barricade Arrest
Free Swinging Arrest Hook (Carrier)	1) Hook Handle Warning Signal 2) Hook Position	Free Swinging Hook 1) Attempt Norm Arrest 2) If unable - 3) Divert 4) If Unable to Divert - 5) Barricade Arrest
Launch Bar Retracted Indicating Unsafe	1) Launch Bar Warning Signal 2) LG Position Ashore → Carrier →	Launch Bar Unsafe 1) Arrest Cables - Remove 2) Normal Landing 3) If Arrest Not Removed 4) EPP - Extend 5) Emerg Gen Sw - TO/Land 6) Mast Gen Sw - Off Reset 7) Cockpit Press - Dump 8) Normal Landing 8) Perform Norm Arrest

TABLE 3-4(Cont)
MMD MESSAGE TABLE - LANDING

Situation	Signal Monitored	MMD Message
Wing Fold Lock Level Not Fully Lowered	1) Wing Fold Advisory Signal 2) LG Position	(Message same as for inflight)
Fire or Engine Overheat (Engine Compartment)	1) Fire Detection Signal 2) Engine Hot Signal 3) LG Position	Engine Hot or Fire 1) Investigate for Fire 2) If Pos - Land ASAP
Fire in Wheel Well	Wheel Well Fire Detect Signal	Wheel Well Fire 1) Get Ext Confirm if Pos 2) If Pos - Land ASAP
Electrical Fire	(Same as for Inflight)	(Same as for Inflight)
Canopy Locking Malfunction	Canopy Advisory Signal	(Same as Inflight)
Rain Remove Hot (>290°F)	Rain Remove Caution Signal	Rain Remove Hot 1) Retard Throt if Pract 2) Rain Remove Sw - Cycle (If Overheat Persists) 3) Min Pract Setting 4) Land Soon as Pract
Master Caution	Master Caution Signal	Master Caution will cause a message to appear on the MMD for the particular malfunction. For the 11 MMD Master Caution Functions see Table 3-1.)
Oxygen Supply Low (≤1 Liter)	Oxygen Low Signal	Oxygen. Low 1) Oxygen ≤ 1 Liter 2) Land Soon as Pract

TABLE 3-4 (Cont.)
MMD MESSAGE TABLE - LANDING

Situation	Signal Monitored	MMD Message
Oxygen System Fails or Main Supply Empty	Oxygen Pressure/Quantity	Oxygen Syst Fail 1) Emerg Oxy Handle - Pull 2) If Breathing Still Dif (And If Below 10K Ft) 3) Remove Mask 4) Cockpit Press - Cab Dump 5) Emerg Vent - Open (If Above 10K Ft - Same as Inflight)
Approach Power Control Dissingage Failure	1) APC Warning Signal 2) Engage Sw Position	APC Dissengage or Fail 1) Force Throttle Forward to Sheer Pin
Approach Power Control Syst in Stby or Disenga	APC Warning Signal	APC Not Engaged 1) APC Sw On If APC Landing Desired
Tactical Computer Failure	Computer Fail Signal	Computer Fail
IMS Platform Failure	IMS Fail Signal	(Message same as for Takeoff)
Radar Altimeter Low Alt Warning	Low Altitude Warning Signal	Low Altitude 1) Below Sel Alt Limit
HUD Failure	HUD Fail Signal	HUD Failure 1) Use Backup System
HUD Hot	HUD Hot Signal	(Message same as for inflight)
ADI Off Flag	ADI Off Flag Signal	ADI Off 1) Use Stby ADI

TABLE 3-5

CHECKLISTS

PRETAKEOFF CHECKLIST

1. Fuel-Checked
2. Wingfold-Checked
3. Flaps-Down
4. Yaw stab. SW-Stab
5. Antiskid SW-Antiskid
6. Trim-Set for T/O
7. Harness-Locked

   (Press_____for Page 2)
8. Launch Bar SW-Off
9. IMS/Head Indicators-CK
10. Canopy-Locked
11. Therm Clos-Off/Locked.
12. Ejct Contr. Handle-Arm
13. Doppler-On
14. Temp contr-10'clock

TAKEOFF CHECKLIST

1. Doub Dat/Pit-Pitot
2. Throttle-MIL
3. Flight Controls-Check
4. Engine Instr-Check
5. Warnings/Cautions-Off
6. Advisories-Checked

LANDING CHECKLIST

1. Throttle-70%RPM
2. Speed Brake-Extend
3. Below 220KIAS
   Wheels-Down
   Flaps-Down
4. Speed Brake-Close
5. Arrest Hook-As Req.
6. Harness-Locked
7. Antiskid-As Req.

TABLE 3-5 (Continued)
CHECKLISTS

POST FLIGHT CHECKLIST

1. Check Warn, Caut, Advis.
2. Log Malfunctions
3. Antiskid SW-Off
4. Nose Gear Steer-Engage
5. Defog SW-Off
6. Cockpit Pr-Cab Dump
7. Canopy-As Desired
8. Cockpit PR-Cab Press
9. Radar-Off
10. Rain Remove-Off

(Press_____For Page 2)

11. Doub Dat/Pitot-Off
12. Flap Handle-Up
13. Gear Gndlocks-Install
14. Wingfold-As Desired
15. Com/Nav Switches-Off
16. IMS Mode SW-Off
17. Wheel Chocks-In Place
18. Tact Comp SW-Off

character and line number requirements that were suggested by NADC for the MMD.

3.1.4 Callup Functions

In addition to the Warning, Caution and Advisory information which is automatically displayed on the MMD, additional information is available for display that can be requested by the pilot and are referred to as callup functions. The callup function would display information such as subsystem status, expendables remaining, or surface positions when requested by the pilot. Typical examples include hydraulic pressure, fuel quantity, or flaps position. These functions are listed on the matrix of Table 2-1 as CU. As a point of further clarification concerning the callup functions, it should be understood that all information classified as callup could be programmed for automatic display during certain mission segments or situations if so desired or deemed necessary.

3.2 New Sensor Requirements

A total of nine new sensors recommended for the A-7E to provide better utilization of the MMD are shown in Table 3-6. Some of the new signals would provide added information to be displayed on the MMD that is not currently available, such as added fire detection coverage. Others are needed to sense that switches for a given function are in the proper position for the message being displayed. This would eliminate the need for manual entry of such information into the computer. The term "sensor" in this case is broad term and includes such things as wire connections and switch closures as well as the addition of thermistors. Each of the new sensors, their functions and justification for adding them is described in following paragraphs.

3.2.1 Fuel Low

An additional fuel level sensor is recommended for the take-off mode since the A-7E Flight Manual recommends no take-off with less than 4,000 pounds of fuel. The sensor would be the same type as the one

TABLE 3-6

New or Add-On "Sensors"

Signal Monitored	Type "Sensor"	Added Ckts Rq'd	Flight Mode
Fuel Low (<4000 Lb)	Thermistor	Signal Conditioner	Take-off
Main DC Power Buss	Wire Connection		All
AFCS Sw. Position	Switch with Extra Poles	Switch Closure Sense	All
Yaw Stab. Sw. Position	Switch with Extra Poles	Switch Closure Sense	All
Fire Detect (Wheel Well)	Heat Sense Element	Detection Control Unit	All
APC Engage Sw. Position	Switch with Extra Set of Poles	Switch Closure Sense	Landing
Radar Altimeter System Fail	*Modification of the Self-Test Circuit for Continuous Monitor		All
HSI Mode Select Monitor	Switch with Extra Set of Poles	Switch Closure Sense	All
ACLS Test	**Modification of the Self-Test Circuit for Continuous Monitor		Landing

The main DC power Buss monitor will require A/D conversion, and there are also 12 existing analog signals that will require A/D conversion before computer processing.

* See paragraph 3.2.6

** See paragraph 3.2.8

currently used to provide the inflight fuel low caution signal, which is a thermistor with associated signal conditioning circuitry. The new sensor would be placed in the fuel system in such a way as to produce a discrete caution signal when the fuel level is less than 4,000 pounds.

3.2.2 Main DC Power Buss

Currently there exists in the main power generator system, a go/no go indicator, with no monitor for the voltage value. It is recommended that the voltage level be monitored so that the computer can supply a caution signal on the MMD to indicate the generator output is approaching a tolerance limit and the actual voltage level can then be monitored if the pilot wishes to do so. The only circuitry necessary to accomplish this task is a wire connection from the main DC power buss to an A/D converter input to the computer that will accept 28 VDC.

3.2.3 AFCS Engage Switch and YAW Stab Switch Positions

In order to display AFCS advisory and failure messages on the MMD, it is necessary for the computer to sense that the AFCS Engage and YAW Stab switches are in the proper positions for the respective messages. The pilot can feel that a malfunction, such as oscillations, has developed in the AFCS and can call up messages to be displayed on the MMD for advice concerning the malfunction, however, an advisory notice that the YAW, PITCH or ROLL is disengaged when the switches have been placed in the engaged position is not a current capability. This capability can be added by a relatively simple means through the incorporation of a new AFCS Engage and Yaw stab switch with an extra set of poles for sensing the switch closure for the respective position.

3.2.4 Fire Detection Sensors

Incorporation of additional fire detection sensors in the wheel wells of the A-7E has been suggested as a necessary addition, since the current fire detection system covers only the engine compartment. The wheel well fire detection system would be either similar to, or an

expansion of the present engine compartment fire detection system with the sensor information interfacing the central computer (TC-2A) for possible display on the MMD.

3.2.5 Approach Power Control Engage Switch Position

In the event the Approach Power Control (APC) malfunctions during an APC landing, the pilot can switch the APC engage switch to OFF and normally regain manual control. However, if the APC fails to disengage after being switched off, a brief message can automatically be flashed on the MMD to remind the pilot what to do. In order to accomplish this, the computer must be able to sense the APC engage switch position and warning signal. The warning signal is an existing function but to sense the switch position, it is recommended that a new switch with an extra set of poles be installed to provide a switch closure signal.

3.2.6 Radar Altimeter System Monitor

The Radar Altimeter currently has a self test function that is initiated manually. It is suggested that the Radar Altimeter System be modified to include a continuous (or periodic) self test to be monitored by the computer so that in the event of a failure, an advisory notice can be displayed on the MMD. The test can be initiated by the computer by supplying a ground ($\pm$0.5VDC) to the altimeter and between tests the computer would be required to supply an open (or 5.0 to 30 VDC). The response from the altimeter for a valid test is a reading of 2.80 to 3.20 VDC which corresponds to an altitude of 100 $\pm$10 ft.

3.2.7 HSI Mode Select Monitor

It is necessary for the computer to monitor the Horizontal Situation Indicator (HSI) mode select switch position in order to provide the MMD with advisory information concerning which mode has been selected. Another reason for monitoring the mode select switch position is that the HSI course deviation alarm signal, which is to be displayed on the MMD, is only effective in the TACAN mode. A relatively simple means to accomplish

this, as has been suggested for some previous functions, is to replace the current mode select switch with one that has an extra set of poles to provide switch closure signals to the computer.

3.2.8 ACLS Test Monitor

The ACLS self test can only be performed when the Radar Beacon monitor switch is the ACLS position. It is necessary then to monitor this switch position in order to allow the computer to initiate the self test and to process the results for display. The switch can be replaced by one having an extra pole to give a switch closure for the test position. The test is initiated by supplying a 28V discrete to the radar beacon. The response for indicating proper operation is a 28V discrete from the radar beacon after two to three seconds from the initiation of the test.

4.0 A-7E/MMD INTERFACE REQUIREMENTS

4.1 Pilot Interface Study

A brief study of the pilot's interface with the MMD was conducted and recommendations were made concerning pilot workload as well as types of information to be displayed on the MMD. The information display study results are presented in Section 2.2.1 and the pilot workload and display design recommendations are presented herein.

4.1.1 Pilot Workload Considerations

The effect on pilot workload is a primary consideration for any new piece of equipment installed in a cockpit. Ideally, any new addition to the cockpit should yield increased efficiency as well as capability. The development of the A-7E from the A-7A/B aircraft is an excellent example of increasing weapon system capability with no increase in operator workload.

One major objective of the MMD therefore is to present the pilot with additional required information only when such information is needed, and with no attendant increase in pilot workload. General guidelines for presentation of information on the MMD with no increase of pilot perceptual/cognitive workload are:

a. Full utilization of MMD system capability to provide clear and concise messages.
b. Exclusion of all messages that do not directly assist the pilot in performing his task.
c. Establishment of a priority system for message display.
d. Full utilization of the priority system in establishing which message to display.
e. Consideration of priority and time constraints in establishing format.
f. Full automation when a fixed response is required because of a fixed set of conditions.

g. Selective addition of sensors to provide the above.

Acceptable psychomotor workload is maintained by implementing the perceptual/cognitive workload criteria plus the following:

a. Holding MMD controls and control actions to a minimum.
b. Automation to the extent that no action is required to obtain a critical (or time critical) message unless it has been preempted by a more critical message. If the full message is preempted, the short form warning/caution is displayed and the full message must be readily available through a single action.
c. Automation to the extent that a maximum of three actions are required to obtain any appropriate message. (An action is defined as reading or actuating.)

Human reliability is enhanced by total workload reduction, careful selection of display format, clarity of each message, and bi-level display dimming with no cutoff.

4.1.2 Display Design Recommendations

The recommended information format to be displayed is a rectangular usable viewing area of 5" x 7" having a character size of 0.18" H x 0.11" W (Ave.) with a stroke width and character spacing of 0.025" and the space between lines of 0.18". For this size viewing area and format, a message of 18 lines with 24 characters per line could be displayed. The actual size of the display, of course, depends upon the installation configuration selected. This selection will also determine the number of message lines and characters that can be displayed. The minimum display size should be no less than 3.65" x 5" with a character size of no less than 0.15" H x 0.09" W and a line spacing of no less than 0.15".

4.2 Software Requirements

This section contains a study of the software requirements for

the MMD which includes a character count of the message text and an upper level functional flow description to determine the necessary computer speed and memory to process and store the MMD data. This study also included an investigation to determine if the TC-2A computer in the A-7E would have adequate reserve operating speed and memory to meet the MMD software requirements.

4.2.1 Character Count

The number of inputs required for generating the MMD messages consists of 46 discretes and 15 analog signals, which includes 9 new discretes and 1 new analog signal. The 87 messages contained in the message table plus the preflight and postflight checklists make up a total of 465 lines of text. The total number of characters contained in the message table of text (including spaces) is 7550, provided that there is no duplication of messages; i.e., if a given message is the same for takeoff and for inflight, only one message will be stored in core. In addition to the messages, there are 15 one line advisory statements with an average of 17 characters per line. The checklists for pretakeoff, takeoff, landing and postflight contains 880 characters which brings the total number of characters to 8655. This would normally require 4328, 16 bit words of memory. There are also 16 callup functions.

4.2.2 Upper Level Functional Flow Chart

The upper level functional flow chart for MMD software is shown in Figure 4-1. The executive function performs the power-up initialization, monitors system operation, schedules task execution, processes interrupts and allows their reoccurrence, determines operating mode, and interfaces with the input/output routines. The data inputs and input data formatting in concert with the executive function, performs data gathering, formats and stores newly received data, and filters or "smoothes" input data as required. The emergency conditions test uses newly received data to make tolerance and limit checks. The display priority determination function makes determinations based upon the results of the emergency conditions test and the pilot requests, and assigns priorities for the display of

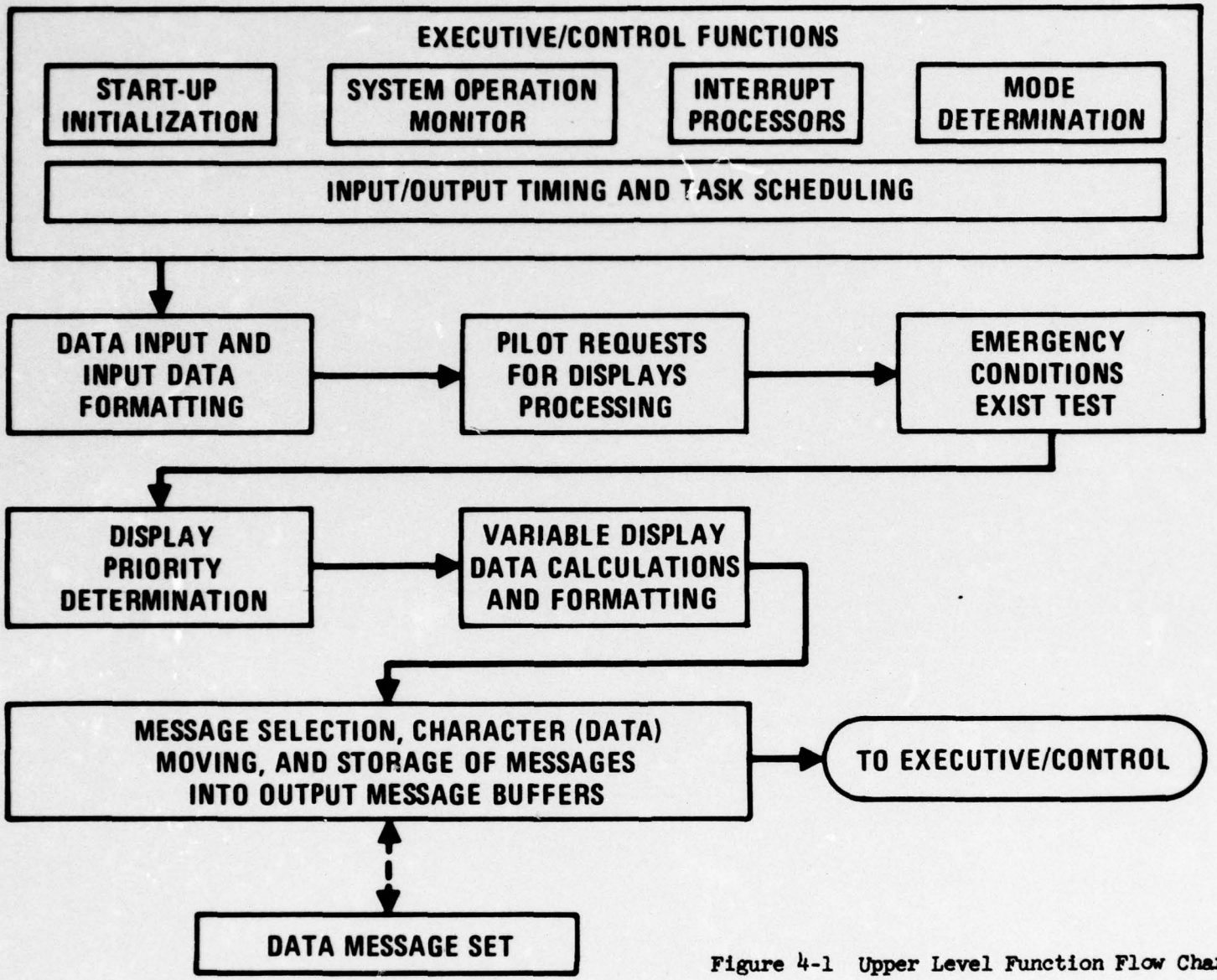

Figure 4-1 Upper Level Function Flow Chart

messages. The variable display data calculations and formatting function performs calculations to convert variable input data to the type of units for display and stores the new data for inclusion in the appropriate message(s). The pilot request processing function in concert with the executive function, processes display requests, determines required information and assigns a tentative priority. The message selection, character (data) moving, and data output function selects requested messages from the data message, adds special message parts as required, does any message concentration requested, and moves appropriate data to the output message buffer(s). The data message set is the set of prestored or "canned" messages to be used as selected for output to the display. Each line of a message will be stored as one of four types:

1. A total statement, i.e., "ABORT TAKEOFF".
2. A true/false statement; i.e., "LANDING GEAR (IS)(IS NOT) UP".
3. A multiple choice statement; i.e., "AFCS (YAW)(PITCH)(ROLL) DISENGAGED".
4. A fill in the blanks statement; i.e., "TURBINE OUTLET PRESS IS ( )".

4.2.3 Estimation of Memory Requirements

An estimation of the total number of words of code for the MMD software is broken down as follows:

1.	Executive/control functions	250
2.	Inputs and input data formatting	400
3.	Emergency conditions exist test (Approx. 150 tests)	600
4.	Display priority determination	50
5.	Variable display data calculations and formatting	70
6.	Pilot request processing	50
* 7.	Message selection, character (data) moving and data outputs	250
8.	Data message set (pre stored)	4400
		6070
	RESERVE	3000
	TOTAL	9070

* Assumes 10, 12 word buffers for outputs to the display.

4.2.4 Estimated Computer Speed Requirements

Certain assumptions had to be made concerning software operating speed, for example, an accumulated table of input data will be available once per second and that pilot requested displays will be honored within one second. Furthermore, it was assumed that a one line (up to 22 characters) CRT message will be either presented in a priority location on the MMD or will be added to existing CRT messages and updated once per second. Also the executive/control functions and some input operations will be performed 16 times per second and that a pilot request, display priority and variable data calculations can occur at a two times per second rate. The computer speed budget for the MMD software functions are as follows:

SOFTWARE FUNCTIONS	OP RATE (TIMES/SEC)	NO OF OPS.	OPS PER SECOND
Executive/Control	16	150	2400
Data Input (Fast Rate)	16	100	1600
Data Input (Slow Rate)	1	200	200
Pilot Requests	2	40	80
Emergency Conditions Test	1	600	600
Display Priority	2	50	100
Variable Data	2	70	140
Message Lines to Buffer	1	130	130
			5250
Reserve Ops Per Second			5000
TOTAL OPS PER SECOND			10,250

4.2.5 TC-2A Computer Capability

The production TC-2A computer for the A-7E will have a 32 K core memory. The present operational flight program (OFP) software, including TRAM, uses approximately 22 K words and also the present OFP software for the TC-2A uses approximately 60% of the available processing time. The estimated MMD software requirements are for 9 K words of memory and an operating rate of approximately 10 K operations per second,

including reserve. It has been concluded therefore, that the production model of the TC-2A computer is capable of storing and processing the necessary MMD software.

4.3 Hardware Requirements

Additional hardware required to interface an MMD to the TC-2A computer in the A-7E will consist primarily of a signal interface box and the new sensors previously described and listed in paragraph 3.2. A brief description of the TC-2A computer and the signal interface box along with the types of signals provided for the MMD are presented in the following paragraphs.

4.3.1 TC-2A Computer Hardware Description

The TC-2A is a general purpose, stored-program, digital computer which contains an arithmetic and a memory section, a built-in signal converter for analog, synchro, and digital inputs and outputs, and a power supply for the regulated dc voltages required by the system. Although most of the computer's work is designed to control instruments and indicators and to receive messages from sensors and other equipment, the pilot has interface capability with the computer through the computer control panel. The computer also has built-in self-test features for continuous monitoring of integral functions. If a processor malfunction occurs, the letters "CMPTR" will appear on the caution panel; however, unless the failure affects program operation, the computer will continue to process information.

4.3.2 MMD/TC-2A Interface

In paragraph 4.2.5 it was concluded from a software standpoint that the TC-2A computer has the capability to store and process all necessary data for an MMD. In order to accomplish the storage and processing of the MMD data, the hardware interface will require a signal interface box between the TC-2A and the functions to be added for the MMD as shown in Figure 4-2. The candidate MMD functions to be processed by the computer

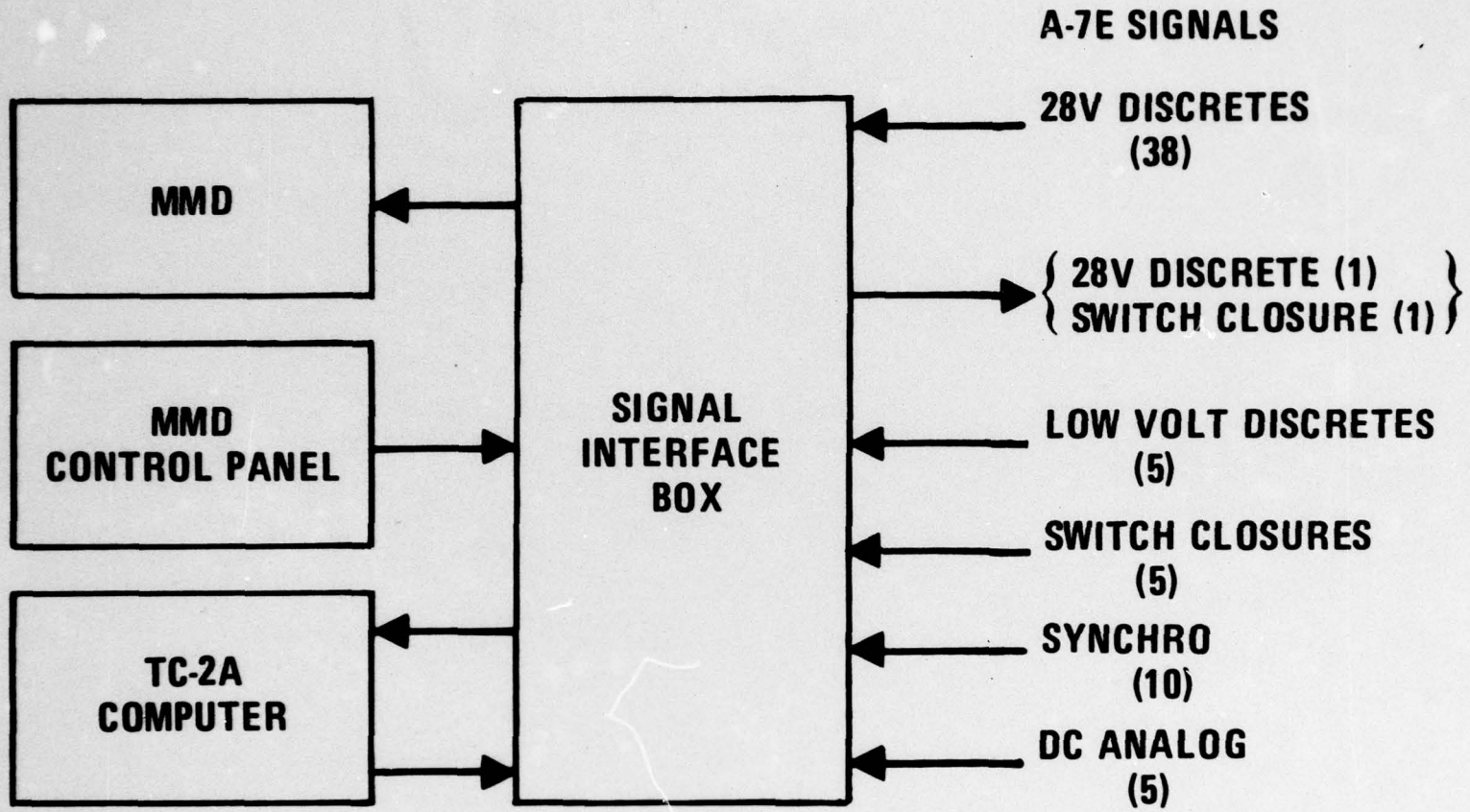

Figure 4-2 A-7E/MMD Signal Interface

include both analog and discrete signals. The analog signals are call-up functions of quantities, positions, status, etc. The discrete signals are produced by a situation that would cause a message or an advisory statement to be automatically displayed on the MMD. Table 4-1 shows the types of interface signals from the sensors to the interface box for each of the MMD messages. In addition to the input signals to the interface box, there are two discrete output signals. A 28 volt discrete output is used to initiate the ACLS test and a switch closure is used to initiate the Radar Altimeter test.

4.3.3 Signal Interface Box

The signal interface box will contain the circuitry necessary to convert and organize the sensor signals into a format to permit the TC-2A computer to process the data and provide output signals to the MMD. This circuitry will include A/D converters for both the DC analog and synchro signals and a microprocessor for formatting, storing and transmitting the interface signals. The analog signals will be converted to digital words for storage in the memory of the microprocessor in the signal interface box. These words are then displayed on the Master Monitor Display when requested by the pilot. The discrete signals will be formatted into 5 bits of address, 13 bits of data and 4 bits of word protocol. The digital words will be then transmitted to the TC-2A via a 20 bit word on a 50 KHZ serial data channel. The TC-2A will output data to the signal interface box by means of another 50 KHZ serial data channel. The data are then formatted in the signal interface box for display on the MMD. Circuitry for special cases such as the Turbine Outlet Pressure and the Master Generator Output will also be included in the interface box to provide a logic level discrete to the computer when either of these signals reach an out of tolerance condition during applicable flight modes. The discretes for these two signals are not shown on the matrix of Table 2-1 nor on Table 4.3.2 because they are not generated by the sensor circuitry. A block diagram of the signal interface box is shown in Figure 4-3.

TABLE 4-1 SIGNAL DESCRIPTION

COMPONENT/ FUNCTION	FUNCTION DESCRIPTION	28 VOLT DISCRETE	LOW VOLT DISCRETE	SWITCH CLOSURE	DC ANALOG	SYNCHRO	NOMINAL VOLTAGE
ENGINE TF41							
TURB OUT PRESS	INCHES OF MERCURY					X	26 VAC
ENGINE OIL	OIL QTY, PRESS, OR FLOW LOW	X					10-28 VDC
ENGINE HOT	TEMP OVER 620°C	X					10-28 VDC
FUEL SYSTEM							
FUEL QUANTITY	FUS TK, TRANS TK & TOT QTY					X	26 VAC
FUEL LOW	FUEL < 1350 LB (< 4000 LB T/O)	X (2)					10-28VDC
ELECT SYSTEM							
MASTER GEN OUT	GENERATOR OUTPUT				X		28 VDC
MASTER GEN	GEN OUT NEAR TOL LIMITS (SOFTWARE)						
HYDRAULIC SYST							
HYDRAULIC PRESS	PC-1,2, OR 3 PRESS < 1500 PSI	X(3)					10-28VDC
PRESSURE, PSI	PC-1, 2, 3 SYST PRESS					X (3)	26 VAC
FLT & TRIM SYST							
ROLL TRIM POS	ROLL POS 13° LFT - 13° RT					X	26 VAC
PITCH TRIM POS	PITCH POS 0 - 15° PITCH					X	26 VAC
FLAP SYSTEM							
TRAIL EDGE POS	POSITION 0° - 40°					X	26 VAC
LEAD EDGE POS	UP, DOWN, IN TRANSIT, UNLOCKED	X					28 VDC
WHEELS/FLAPS*	WHLS/FLAPS BOTH NOT UP OR DN	X					10-28VDC
AFCS							
ACTUATOR POS	PITCH, ROLL, YAW ACTUATOR POS				X (3)		±50 MV
YAW STAB	DISENGA OR YAW SW NOT IN STAB	X	X (2)				10-28VDC
PITCH AFCS	DISENGAGED	X					10-28VDC
ROLL AFCS	DISENGAGED	X					10-28VDC

*SHOWN ALSO UNDER LANDING GEAR

TABLE 4-1 (Cont'd) SIGNAL DESCRIPTION

COMPONENT/ FUNCTION	FUNCTION DESCRIPTION	28 VOLT DISCRETE	28 VOLT DISCRETE	SWITCH CLOSURE	DC ANALOG	SYNCHRO	NOMINAL VOLTAGE
SPEED BRAKE							
POS INDICATOR	CLO (0°) TO FULLY OPEN (60°)					X	26 VAC
SPEED BRAKE	SPEED BRAKE NOT CLOSED	X					10-28 VDC
LANDING GEAR							
LG POSITION	UP-IN TRANSIT - DN	X					28-0-28
LANDING GEAR							
LG POSITION	UP-DN-IN TRANSIT	X					10-28 VDC
HANDLE WARNING	NOT LOCKED IN POSITION	X					10-28 VDC
WHEELS/FLAPS*	BOTH NOT UP OR DOWN	X					10-28 VDC
NOSE GEAR STEER	NOSE GEAR STEERING ENGAGED	X					10-28 VDC
WHEEL BRAKES							
ANTI-SKID	MALFUNCTION, SWITCH TO MANUAL	X					10-28 VDC
TAIL HOOK							
HOOK HNDL WARN	HOOK NOT IN SELECTED POSITION	X					10-28 VDC
CATAPULT SYS							
LAUNCH BAR	SWITCH IN EXTEND OR MALFUNCT	X					10-28 VDC
WINGFOLD SYS							
WINGFOLD	LOCK LEVER NOT FULLY LOWERED	X					10-28 VDC
FIRE DETECT SYS							
FIRE	ENGINE COMP FIRE OR OVERHEAT	X					10-28 VDC
FIRE	WHEEL WELL FIRE	X					10-28 VDC
CANOPY							
CANOPY	CANOPY UNLOCKED	X					10-28 VDC
AIR CONDITION							
RAIN REMOVE HOT	DUCT TEMP EXCEEDING 290°F	X					10-28VDC

*SHOWN ALSO UNDER FLAP SYSTEM

TABLE 4-1 (Cont'd) SIGNAL DESCRIPTION

COMPONENT/ FUNCTION	FUNCTION DESCRIPTION	28 VOLT DISCRETE	LOW VOLT DISCRETE	SWITCH CLOSURE	DC ANALOG	SYNCHRO	NOMINAL VOLTAGE
MASTER CAUTION							
CAUTION	MALFUNCTION OR ABNORM COND	X					10-28VDC
OXYGEN SYSTEM							
QUANTITY	QTY LIQUID OXYGEN (LITERS)					X	26 VAC
OXYGEN	≤ 1 LITER OR REG PRESS ≤ 42 PSI	X					10-28VDC
APPRO PWR CONTR							
APPRO PWR CONTR	SYS IN STBY OR DISENGAGED	X		X			10-28VDC
ANGLE OF ATTACK							
ANGLE OF ATTACK	RANGE OF 0 TO 30 UNITS				X		0-28 VDC
TACT COMPUTER							
COMPUTER	COMPUTER FAILURE	X					10-28VDC
IMS							
IMS NOT ALIGN	IMS NOT ALIGN; IMS/DPLR DIFF	X					10-28VDC
PLATFORM	IMS SYSTEM FAILURE	X					10-28VDC
DOPPLER RADAR							
DOPPLER	UNRELIABLE INFO	X					10-28VDC
AIR DATA CMPTR							
ADC	FAILURE IN ADC SYST	X					10-28VDC
FWD LOOK RADAR							
FAIL	RADAR FAIL, CLIMB COMP IN TF	X					10-28VDC
RADAR ALT							
LOW ALT WARN	ALT BELOW SEL INDEX MARK	X					10-28VDC
SYS MONITOR	SYSTEM MALFUNCTION		X				2.8-3.2V

TABLE 4-1 (Cont'd) SIGNAL DESCRIPTION

COMPONENT/ FUNCTION	FUNCTION DESCRIPTION	28 VOLT DISCRETE	LOW VOLT DISCRETE	SWITCH CLOSURE	DC ANALOG	SYNCHRO	NOMINAL VOLTAGE
HUD							
HUD FAIL	HUD FAILURE	X					10-28 V
HUD HOT	OVERHEAT CONDITION	X					10-28 V
PROJ MAP DISPL FAIL	FLAG-PMDS FAILURE		X				0 V=FAIL 5 V=OK
ADI OFF FLAG	FAIL: IMS UNREADABLE		X				<245 MV =FAIL
HSI MODE	MODE SELECT MONITOR			X			<245 MV
CRSE DEV ALARM	INADEQUATE SIG ON #1 POINTER		X				=FAIL
OFF FLAG	PWR OR INDICATOR FAIL		X				0 V=FAIL 5 V=OK
ACLS ACLS TEST	TESTS FOR ACLS MALFUNCTION	X		X			28 V

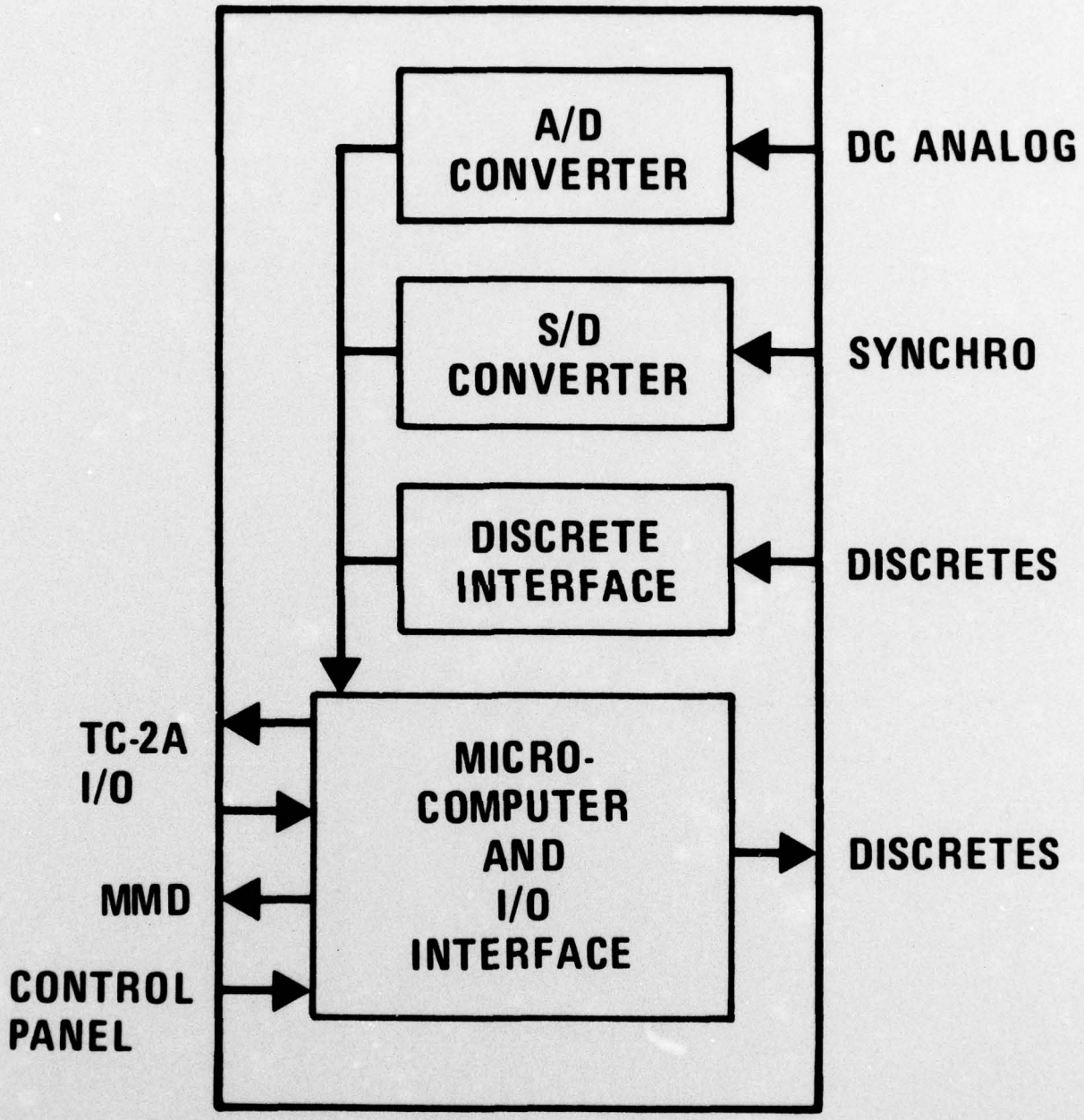

Figure 4-3 Interface Box

5.0 CONCLUSIONS AND RECOMMENDATIONS

The feasibility of incorporating a Master Monitor Display into an A-7E has been established by the results of this study. An alpha-numeric type display operated under control of the TC-2A computer in conjunction with the necessary pilot-operated controls offers a considerable increase in the usefull information presented to the pilot in comparison to the current dedicated instruments. Messages to aid the pilot in decision-making in cases of emergency or advisory statements to inform him of situations and conditions are displayed without increasing the pilot workload since the control and display functions are under software control.

A study of the MMD software requirements along with an investigation of the TC-2A computer capability and its dedicated use indicates that the TC-2A computer in the A-7E has adequate speed and sufficient memory such that it is capable of storing and processing the necessary MMD software. The computer can provide data to the MMD from the existing aircraft sensors with a minimum of modifications or additions. The hardware interface for the MMD can be accomplished by utilizing an interface box containing a microcomputer with memory and I/O interface circuitry between the MMD and the TC-2A computer in the A-7E.

This study only addressed the MMD which is one of five master displays in the AIDS concept. A similar feasibility study is recommended for the full AIDS integration in an A-7 type aircraft to identify the requirements and special aircraft integration constraints which must be considered in the installation of the integrated display concept in a tactical aircraft.

LIST OF ABBREVIATIONS, TERMS

Abnorm	Abnormal
A/C	Aircraft
Accel	Accelerate
Accum	Accumulate
Acent	Ascent
ACL RDY	Discrete light on ACLS
ACLS	Automatic Carrier Landing System
A/D	Analog-to-Digital
ADC	Air Data Computer
ADF	Automatic Direction Finder
ADI	Attitude Director Indicator
Advis	Advisory
AFCS	Automatic Flight Control System
AGR	Air-to-Ground Ranging
AIDS	Advanced Integrated Display System
AIMS	Automatic Altitude Reporting System
Airspd	Airspeed
Alt	Altitude, Altimeter
AN/ARA-63	Precision Approach Receiver
AOA	Angle of Attack
APC	Approach Power Control
Appro	Approach
APX-72	AIMS Transponder System
ARC-51	UHF Command Radio
Avail	Available
Brg	Bearing
Cab	Cabin
Caut	Caution
Chk	Check
Clo	Close(d), Closure

CMD CTL	Discrete Light on ACLS
Cmptr	Computer
Comd	Command
Comm	Communications
Comp	Compartment
Compen	Compensation
Contr	Control
Crse	Coarse
Dat	Datum
Doub	Double
Del	Deliver(ed)
Detect	Detection
Dev	Deviation
Diff	Difference, Different
Disenga	Disengaged
Displ	Displacement
Dist	Distance
Dplr	Doppler
ECM	Electronic Counter Measures
Ejct	Eject
EMD	Engine Management Display
Emer	Emergency
Eng	Engine
Enga	Engage(d)
EPP	Emergency Power Package
Ext	Extend(ed)
Fail	Failure
Flg	Flag
FLR	Forward Looking Radar

Flt	Flight
FPM	Feet Per Minute
Freq	Frequency
Fus	Fuselage
GE	General Electric
Gnd	Ground
Gen	Generator
Hdg	Heading
Hg	Mercury
Hndl	Handle
Horiz	Horizontal
HSI	Horizontal Situation Indicator
HUD	Head-Up-Display
Hyd	Hydraulic
IFF	Identification, Friend or Foe
IMS	Inertia Measurement System
Ind	Indicator, Indication
Info	Information
Inop	Inoperative
Inst	Instrument
Intero	Interrogate, Interrogation
Iso	Isolate
KIAS	Knots Indicated Airspeed
Lat	Latitude
Ldg	Landing
Lft	Left
LG	Landing Gear

LK	Link
Mag	Magnetic
Man	Manual
Mil	Military
MMD	Master Monitor Display
MSLP	Mean Sea Level Pressure
Msg	Message
NADC	Naval Air Development Center
NATOPS	Naval Air Training and Operating Procedures Standardization
Nav	Navigation
NAVAIR	Naval Aeronautics Systems Command
Norm	Normal
OFP	Operational Flight Program
Oper	Operate, Operation
Oxy	Oxygen
PC-1, 2, 3	Power Control System (Hydraulic)
Pit	Pitot
PMDS	Projected Map Display System
Pneu	Pneumatic
Pos	Position
Press	Pressure
PSI	Pounds Per Square Inch
Pt	Pointer
Pwr	Power
Qty	Quantity

Rec	Receive
Reg	Regulator
Req	Required
Ret	Retract(ed)
RCVR	Receiver
RHAW	Radar Homing and Warning
Rt	Right
Rud	Rudder
S/D	Synchro-to-Digital
Sel	Select
Sig	Signal
Spd	Speed
Stab	Stabilization
Stby	Standby
SW	Switch
Syst	System
TAC	TACAN
TACAN	Tactical Air Navigation
TC-2A	Tactical Computer in A-7E
Temp	Temperature
TF	Terrain Following
Therm	Thermal
TILT	Discrete Light on ALCS
TK	Tank
T/O	Takeoff
Tol	Tolerance
TOT	Turbine Outlet Temperature
Tot	Total
TRAM	Target Recognition and Multisensor
Trans	Transfer(ed)

UHF	Ultra High Frequency
Vert	Vertical
Warn	Warning
Whls	Wheels
XMTR	Transmitter